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Vol. 245 **APRIL, 1948** **No. 4**

A STUDY OF PATENT POLICIES IN EDUCATIONAL INSTITUTIONS, GIVING SPECIFIC ATTENTION TO THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

BY

VINCENT LEE McKUSICK, S.M.[1]

(*Continued from March issue.*)

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* A paper presented in the graduate seminar in electrical engineering at Massachusetts Institute of Technology by the author.

[1] Now a student at Harvard Law School, Cambridge, Mass.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

CHAPTER III
M.I.T. PATENT POLICY[1]

A. *Development of a Patent Policy at the Institute*

Before 1930 the M.I.T. experience with patents was not too different from that of every comparable educational institution. Patentable inventions had been made, and in each case tradition was followed. Either no patent was obtained or else it was considered strictly the property and individual concern of the inventor. In some instances the inventor, as Professor Hardy [2] with his spectrophotometer or color analyzer, applied to the Institute for a decision in regard to ownership of the invention and was given a *carte blanche* to develop the patent right as his own.

In 1932 an all-faculty committee [3] studied the patent problem and drew up a statement of policy regarding inventions. This statement, approved by the Faculty and by the Institute Executive Committee, has remained essentially unchanged as the fundamental patent policy of the Institute. Its context, which deals only in general terms with the property rights in inventions, may be summarized as follows:

1. Inventions from research financed entirely by the Institute shall be the Institute's exclusive property, from which M.I.T. may receive all benefits.
2. The Institute will have no rights in inventions
   (a) toward which the Institute contributes substantially nothing in funds or in time of a staff member, or
   (b) which are made by students whether paying tuition or receiving scholarship aid (The Institute is considered to administer, and not contribute, scholarship funds.), or
   (c) which are made in a program of research financed *in toto* (including overhead) by an outside sponsor.[4]
3. Intermediate cases will be handled on their own merit by special arrangement, in absence of which, title to the patent remains with the Institute.

This policy statement, formulated as it was (and only could be) in generalizations, has been the basis for Patent Committee decisions of equity since 1932. Enhanced by its brevity and clearness it has been voluntarily accepted by the staff members, making unnecessary the

[1] The writer is indebted to Dean John W. M. Bunker, who, until recently, was Chairman of the M.I.T. Patent Committees, for much of the material presented in this chapter.

[2] Statement by Dr. Arthur C. Hardy to Miss Ahearn, of the M.I.T. patent office, March 5, 1947.

[3] Ref. 48. (The reference numbers of the footnotes correspond with the numbered items of the bibliography at the end of this paper.)

[4] The Institute no longer gives up *all* rights in inventions made in a research program, financed entirely by an *outside* party. (See the section "Patent Policy in Regard to D.I.C. Contracts," later in this chapter.)

compulsory reporting of inventions as was the regulation at the University of California for some years.[5]

The motivation for the 1932 patent statement was probably much the same as that indicated in the preceding chapter for many other universities. The economic winds were blowing toward a better-defined policy. At the Institute research related to Vitamin D was in progress [6] and the early Wisconsin experience with the Steenbock patent was not wasted on the committee. A member of the faculty committee said at that time, "I wish to emphasize that *control* and not *royalties* was the objective." [7] By that statement he evidently meant that the purpose of the new patent policy was primarily to avoid misappropriation of Institute discoveries and to encourage their public use.

Up to 1937 some thirty patents had been assigned directly to the Institute and managed by the Patent Committee. In that year an arrangement was made with Research Corporation to handle all the legal and commercial aspects of such Institute inventions as might be turned over to it.[8] Research Corporation opened a Boston office directed by Carroll L. Wilson, former assistant to President Compton and at present General Manager of the U. S. Atomic Energy Commission. The office was moved to M.I.T. during the war; about a year ago the files were moved to the New York office of Research Corporation to coordinate all patent management in a separate division there.

The original ten-year agreement between the Institute and Research Corporation was renewed recently. During 1946 the earlier agreement was considered in the light of experience and minor modifications were made, the chief change being a simplification of the method for dividing income between the Institute and Research Corporation.

Research Corporation cannot relieve the Patent Committee of many administrative decisions. At the request of the faculty Patent Committee, a new administrative Committee on Patent Management assumed responsibility in 1942 for making policy for patent management.

During the war a patent office with two patent attorneys working on a part-time basis was set up in the Division of Industrial Cooperation to handle patent problems arising out of the government research contracts. This office, while finishing up government patent matters, is continuing to give the D.I.C. assistance in its industrial patent problems and to expedite the work of the faculty Patent Committee and the Patent Management Committee.

B. *The M.I.T. Patent Policy*

A patent policy by its nature cannot be written down as an immutable law to be applied without reservation in every case. Whether

[5] Ref. 40, p. 122.
[6] Ref. 45, p. 142 ff.
[7] Prof. William F. Ryan in ref. 32, p. 209. Italics are supplied by this present writer.
[8] Ref. 20.

the problem involves decisions of ownership, licensing, or patent litigation, the case must be weighed on its own merits. Generalizations here are dangerous, and any 'policy' reported herein should be interpreted only as the trend of the 15 years' Institute experience and as the current approach to the problems.

Quite as much a part of the Institute patent policy as the specific treatment of the problems to be considered below in the general attitude of the Patent Committees toward patents.[9] First, it is their hope that successful patent protection and management can be effected without the Institute and its staff becoming excessively patent conscious. They realize the dangers to university research that might result from careless management of patents or too great emphasis placed upon patenting by staff members. At the same time they believe that a healthy faculty feeling is created in the knowledge that patentable inventions will not be thrown to the patent-sharks or be allowed to go unused. The Institute patent machinery should be considered, they feel, a major institutional aid available to the individual inventor. Finally, they intend that patent delays should not hold up publication through scientific journals. Publication anywhere of information in regard to an invention usually bars obtaining a patent in foreign countries; however, once application is filed in this country publication may be made without losing the foreign patent rights. No case where patenting has seriously delayed publication is known to have occurred at M.I.T.

1. *Ownership*

The formal 1932 statement, already summarized, forms the basis for the question that must be answered in each case; namely, who owns the property rights to an invention or other development at the Institute? Since no formal agreement in regard to patents exists between staff members and the Institute (except in some cooperative research with outside sponsorship) each situation must be treated individually. Some special cases have developed further refinements in the stated policy. For instance, the Institute is considered to have no equity in developments resulting from consulting activities by staff members. As a 1937 statement of the Patent Committee [10] put it, these inventions should be handled as "provided for in the usual code of ethics of consulting engineers." The Institute, believing better teaching results, encourages outside consulting by the faculty, but it can take no responsibility for the success or failure of staff members as consultants. A patent-conscious staff member could reserve for himself the benefits from his patents by making prior arrangements for their commerciali-

[9] Gleaned from talks with members of the Institute Patent Committees.
[10] Ref. 20, p. 350.

zation with outside concerns in the course of his consulting activities. Such a circumventing of Institute policy is better combated by building faculty good will than by prescribing arbitrary rules of procedure.

The government research contracts, totaling $93,000,000 in the war period,[11] have posed a new type of ownership problem. The Institute has had little to say in its solution except in bargaining for the form of the original contract. The government used two standard patent contract forms: the "long form" and the "short form." The short form states in a few words that all patents developed under the contract shall belong to the government. The long form gives prior rights to all patents to the contractor, i.e. the Institute, with the provision that the government may receive a royalty-free, unrestricted license, and provides that all inventions on which the contractor does not elect to patent be reported to the government. It then may patent them. The Radiation Laboratory operated under a contract provision of the short form, but in most of the four hundred other contracts the long form was used. The Institute, believing that a university makes a sizable contribution to government-sponsored research through the accumulated experience of its faculty and in overhead expenses [12] that cannot be adequately covered by contract provisions, preferred the long form. The first contribution was made less exclusively by M.I.T. in the Radiation Laboratory, the staff of which represented a great many universities. All these considerations are wrapped up with the total problem of government sponsorship of research, and are outside the scope of this study. The interested reader will find a more complete statement of Institute policy in President Compton's report of 1945.

Graduate students who now do theses while employed under a government contract are treated as all other employees rather than as students receiving scholarship aid. By the provisions of the government contract, the Institute is required to be in a position to give to the government licenses on all patentable discoveries developed under the contract.

The rights to inventions from industry-sponsored research will be specifically considered later in this chapter.

2. *Attitude toward Income from Patents*

This attitude is at the heart of any patent policy. The Institute Patent Committee apparently believes that income is secondary to control and development of patentable inventions in the public interest. However, it is realized at the same time that an Institute administrator

[11] Ref. 35, p. 7.

[12] Ref. 35. The M.I.T. Special Bulletin, "Policy Relating to Governmental Contracts for Research at the Institute" (November, 1944), explains the philosophy behind Institute policy re government contracts.

has responsibilities to manage patent property in the same business-like manner as he does other property. Thus, the policy is to receive all possible income that is consistent with the best public relations. Drawing the border-line is the difficulty.

In this connection portions of President Compton's talk to the Alumni Association [13] on January 30, 1943 are pertinent:

> We have found how to handle patents in an educational institution of our type in a manner which is clearly in the public benefit and which cannot endanger the institution from a *public relations* or a *legal** point-of-view.... The indications at the present time are that income from this source may be substantial enough to strengthen in a significant way our facilities and opportunities.

The Research Corporation agreement with the Institute provides that 50 per cent. of gross income, after certain special expenses are deducted, is returned on Institute patents. The "special" expenses include costs of foreign patents, of developmental research which the Institute may authorze in writing, and of certain litigation expenses.

Pharmaceutical or public health patents, considered by a few universities as improper sources of income, are not differentiated by the Institute in its patent policy. In practical terms the borderline between a public health patent and an engineering patent is often a tenuous one. Except that public opinion may be especially susceptible to irritation by seeming profiteering on the public's ills, it is difficult to see any theoretical consideration that allows an educational institution to concern itself any *less* with the general welfare in regard to engineering patents than in regard to pharmaceutical discoveries.

3. *Reward to the Inventor*

The standard return to the inventor, established by the M.I.T. Patent Committee, is 7 per cent of the gross returns from patents. Seven per cent follows the pattern set by Research Corporation. The preceding chapter indicated the wide variation among universities in this regard. One patent administrator of long practical experience has said that the 7 per cent gross is, for the average invention, about as good as an independent research foundation's 15 per cent grant. Even for a successful invention 15 to 25 per cent of the receipts, it is estimated, is by necessity expended in completing, developing and protecting the invention.

The Patent Committees [14] intend that the reward to the inventor should serve two purposes:

a. Patentable invention should have its main reward in salary and staff promotions in the same way that unpatentable scientific discoveries are rewarded and in "that support of staff research,

[13] Ref. 22.

* Italics are supplied by this present writer.

[14] Ref. 20, p. 348; ref. 34, pages unnumbered.

which [is] due to those who contribute to the welfare of the Institute and to the advancement of science."

b. The inventor should also participate directly in the proceeds of his invention.

4. *Licensing Policy*

Research Corporation has a policy of giving only non-exclusive and unrestricted licenses. It has been highly successful in inducing industry to use its patents on this non-preferential basis.[15] In view of the fact that Research Corporation has generally limited its acceptance of patents to those of a fundamental or basic nature, just the type of patent that usually demands further developmental expenditures and thus requires exclusive licensing, the success of its non-exclusive licensing policy is especially significant. The Research Corporation's "servicing" program, particularly for the Cottrell electrostatic-precipitation patents, bears part of the developmental costs which business concerns usually believe can be recouped only through an exclusive license. The licensee also can hope to obtain compensation for his own efforts in developing the invention from ownership of later improvement patents.

Cases sometimes arise in which the unrestricted licensing policy is clearly failing to bring a valuable patent into public use. One such case, that of the Van de Graaff patent group, will be discussed in the succeeding chapter. Research Corporation, after conference with the Patent Management Committee of the Institute, may give an exclusive license for a limited period or for a particular use. Although the non-exclusive licensing policy is preferred, the public welfare in the development of a useful invention may demand modification of that policy.

5. *Patent Policy in Regard to D.I.C. Contracts* [16]

Before research sponsored at the Institute by an industrial concern through the Division of Industrial Cooperation is undertaken, a contract specifying the disposition of patent rights is accepted by all parties concerned. Although the original Institute policy statement gave full patent rights to the industry financing a research program *in toto*, even by 1937 "such closed or confidential research projects" were rare.[17] The tendency is to avoid contracts with industry which sign away all Institute rights to resulting inventions. The philosophy behind this stand is apparently twofold.

In the first place, the Division of Industrial Cooperation feels a responsibility to the public and private contributors to the Institute endowment quite as strongly as any momentary responsibility to a particular sponsor. Secondly, the Division of Industrial Cooperation realizes that inventions and discoveries are not spawned simply by the

[15] Ref. 44, p. 9.

[16] From this writer's talk with *D.I.C.* Director, N. M. Sage, March 21, 1947.

[17] Ref. 20, p. 350.

expenditure of funds, but usually result only from accumulated experience in the art, experience toward which the Institute has contributed substantially. Whether a valuable invention is made under a particular contract is highly accidental.

This philosophy is tempered by the practical considerations that industry should be offered some attraction to sponsor worth-while research, and that once an invention is made, at least a limited protection for the manufacturer is often necessary to bring it to public use.

The standard agreement with a cooperating industry which pays complete cost for the research has these patent provisions:

1. The sponsor has the right (or responsibility) to file and prosecute at its own expense all patent applications with assignment to the sponsor.
2. The sponsor has full rights to the invention, with the exceptions that
   (a) to such uses as the invention may have outside the sponsored "field of research" the Institute reserves full rights, the sponsor continuing to hold only the free right to employ the invention in his own business, and
   (b) after 10 years from the date of filing the patent application the Institute has the free right to grant licenses to others.

In effect the sponsor is given free use of any invention resulting from the cooperative research for the life of the patent and a monopoly use of the invention in the restricted "field of research" for about half the patent duration. Ten years was chosen as a sufficient time to recoup the sponsor's expenses and to bring the invention into public use. D.I.C. contracts with industry, although they have totaled about $800,000 annually in recent years,[18] have not been the prolific patent-producers they might be expected to be under these arrangements. Only three groups of patents are now assigned to the industries sponsoring the research. One of these patent groups applies to the improvements on high-frequency capacitors made by Professor Balsbaugh and is assigned to the original sponsor, Aircraft-Marine Products, Inc.

Before the above method for giving preferential treatment to the industrial sponsor was instituted, industry commonly received the patents by assignment, but the Institute reserved the right to license others, in which case the royalty fees were divided equally between the Institute and the sponsor.

6. *Litigation Policy*

Research Corporation, while avoiding aggressive litigation, does everything possible to protect its licensees in the use of its patents. The fundamental nature of the patents it accepts, as noted before, has

[18] Ref. 35.

probably aided in the legal successes of Research Corporation. Another factor is its concern with public interest in licensing. In the case of several Institute patents interference proceedings in the Patent Office and infringement suits have occurred. There appears to be a tendency to settle these disputes outside of court on the basis of the non-legal equities of each situation. For instance, Research Corporation was involved in an interference with Bell Laboratories in regard to the Barrow inventions for a hollow-tube transmission system. The parties to the interferences came to terms before any decision by the Patent Office, with the result that Bell Laboratories paid a sizable lump sum for a non-exclusive license in the communications field. In the case of the Cartwright-Turner patents for reducing light reflections from surfaces of light transmitting articles, such as lenses, investigation in the course of infringement suits against Eastman-Kodak indicated that there was considerable question as to the priority of invention. As a result, the several licensees under the patents were notified that their rights under certain claims could not be protected and further royalties would be collected only on a much narrower basis.

Their semi-public nature is probably an element of both strength and weakness in the position of the Institute and its agent, Research Corporation, in patent litigation. Since public relations must be kept in mind constantly and since the Institute can never really dissociate itself from its agent, litigation cannot be pushed with the legal ferocity which is characteristic of suits between competitive industries. On the other hand, respect for the educational institution, if properly maintained, can keep legal disputes involving a university on a higher plane than industrial conflicts. Evidence indicates that business concerns are willing to bargain (and in many cases to make generous concessions to universities) rather than fight to the bitter end.

CHAPTER IV

HOW THE M.I.T. PATENT POLICY IS CARRIED OUT

Policies are effective only if procedures carry them out as intended by their authors. Patent policies in particular may fail or succeed by the procedures affecting the university's relations with its staff, with the public, and with industry.

The procedures used at M.I.T. in obtaining a patent and in its management will first be outlined briefly. Then a procedural history of representative groups of patents will be traced in detail.

A. *Patent Procedures* [1]

The first step in the patent procedure is taken voluntarily by the individual staff member. Having made a discovery which he believes

[1] Ref. 34, pages not numbered. The illustrative material used in this section comes chiefly from talks with Miss Catherine Ahearn of the M.I.T. patent office.

should be patented, he submits a complete description to the Patent Committee on a standard disclosure form provided by the committee. The Patent Committee then determines probable invention, the division of equity, and the proper inventor reward and refers the case to the Committee on Patent Management. The Patent Management Committee may decide either to prosecute patent application or to waive all Institute rights to the invention in favor of the inventor.

1. *The Patent Committees*

The committees under a single chairman [2] direct M.I.T. patents. The Patent Committee, consisting chiefly of faculty members, has the the three duties already mentioned.

a. It determines inventorship and dates of conception, of disclosure, and of reduction-to-practice from the disclosure statement of the staff member.
b. It weighs the equities of the Institute, of the inventor, and of other parties in the invention.
c. It recommends to the Management Committee the extent of inventor participation in financial returns.

In short, the Patent Committee interprets the formal 1932 policy statement in regard to each case brought to it.

The Patent Management Committee, with membership including the D.I.C. Director, the Treasurer of the Institute, and the Executive Vice-President, handles all the management problems connected with obtaining the patent and putting it to use. The Management Committee may apply any of three alternative methods for the administration of an Institute patent. The Committee may manage the patent directly in the name of the Institute, it may offer it to Research Corporation, or it may turn it over to some other agency or corporation for administration.

Although a few patents, as that for the Brown-Forrester remote-control system, are administered directly by the Institute as a temporary expedient, an outside agency for administration is generally preferred. A standing arrangement is kept with Research Corporation and a very great majority of the Institute patents are assigned to that Corporation. [3] However, the Institute is free to offer only such patents as it wishes and the Research Corporation may refuse to accept an assignment.

In some cases where some company other than Research Corporation

[2] Prof. John E. Burchard was recently appointed chairman of the patent committees.

[3] Some 88 patents and 41 patent applications on Institute inventions are now under Research Corporation administration. These patents fall into about twenty-four groups such as the Van de Graaff group of eight patents and two applications. Only four issued patents are under other administration than Research Corporation.

is better prepared to commercialize the patent, that company may be chosen to act as agent in the same capacity as Research Corporation. For instance, the nine patent applications pending on a low-temperature refrigeration system and liquid-oxygen-making equipment, of which Collins, McMahon, and Keyes are inventors, have been assigned to Arthur D. Little, Inc. The group of inventions was made partly under an O.S.R.D. contract. The Little company is specifically given the right to license other firms; the Institute receives two-thirds of all net proceeds. This assignment, although apparently equivalent to an exclusive license, must be interpreted in light of two facts. A. D. Little Company, as a research and consulting firm, naturally would be interested in licensing manufacturers and, secondly, a controlling share in A. D. Little is owned by the Institute. Before 1936 the Institute gained some of the advantages of the present arrangement with Research Corporation by agreements similar to this one with A. D. Little. The Milas patents for preparation of anti-rachitic substances (Vitamin D) were originally assigned to duPont Company which paid royalties to the Institute and assumed responsibility for all litigation.

2. *Research Corporation*

Research Corporation is a three-headed organization. It is a manufacturing and engineering concern, a foundation dispersing research funds, and a patent-managing agency. With a separate division for handling patents assigned to it by universities, Research Corporation is putting increased emphasis on the last function. It now holds patents in some 49 major technical groups, such as vitamins, textiles, radio communications, and automotive engineering.

Research Corporation, as contrasted with a university research foundation, enjoys two major procedural advantages.[4] It exercises, in the first place, a greater bargaining power by virtue of the large groups of patents which it holds in allied fields. It can drive better bargains with industry than a university can in the case of an isolated patent. Secondly, patent management is its specialty. Research Corporation has standing contacts with industrial users of patents, it has the manpower that universities lack, and it has sufficient patents to gain the efficiency incident to specialization within the patent-management division.

In procedure Research Corporation takes responsibility for all management problems from prosecution of the patent application on. It does no manufacturing or developmental engineering, as it has performed for the Cottrell patents, although its officers are on the lookout for a product which would complement the electrostatic-precipitation equipment which is a cyclical capital good. Further developmental re-

[4] This writer's talk with Dr. Joseph W. Barker, President of Research Corporation, New York City, April 10, 1947.

search on a patented invention, if necessary, is encouraged in two ways:

a. A company, or group of companies, may be found to sponsor further research at a university for which the sponsors receive preferential treatment in licensing the original patent. A group of pharmaceutical companies was organized to finance continued research on Vitamin A by Dr. Milas at the Institute.

b. A company may be encouraged to perform the developmental research by an exclusive license until the company has recouped twice the developmental cost.

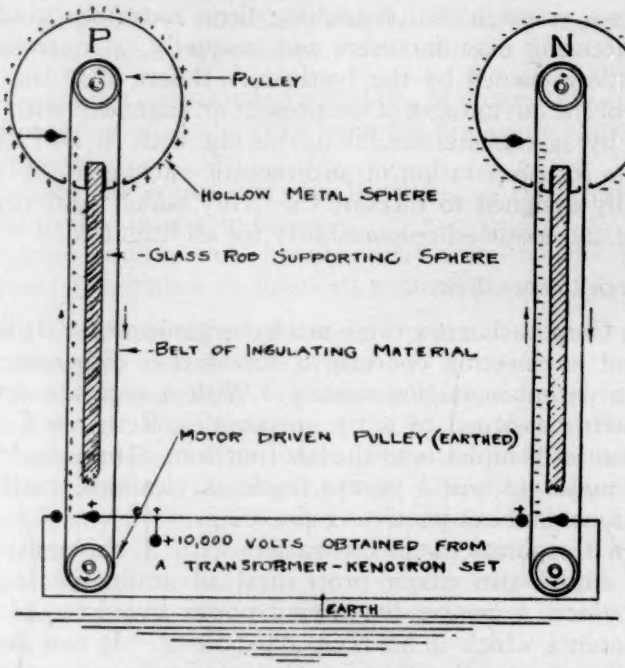

FIG. 1. Essential parts of the Van de Graaff generator.
(From ref. 31, p. 150.)

Both methods are frowned upon by Research Corporation; it would much prefer to hold to a policy of non-exclusive licensing.

B. *Policy and Procedure for Certain Patent Groups*

Two patent groups have been selected for a thorough investigation to show how the M.I.T. patent policy is managed. One group involves engineering inventions; the other, public health. Neither is strictly representative of M.I.T. patent procedure as it is now carried out; each is a special case. However, since both groups date from the early thirties, their developments demonstrate the vicissitudes through which patent management at the Institute has passed.

1. *The Van de Graaff Group* [5]

The Van de Graaff electrostatic generator[6] makes possible production of a direct current potential of several million volts and a steady current of a few milliamperes. It has been used in high-voltage X-ray equipment, in investigation of high-voltage insulation and other phenomena, and in nuclear research for accelerating charged particles. The generator consists essentially of a high-voltage terminal resting upon an insulating column and of a rapidly-moving non-conducting belt which transfers electric charge between ground and the terminal to build up a high voltage on the latter. The charge is sprayed on the belt from corona points supplied with a direct current potential from a transformer-rectifier set; it may be removed by similar corona points at the terminal or by a self-induction arrangement.

Application for the basic patent on the Van de Graaff electrostatic generator was filed soon after Prof. Van de Graaff came to the Institute from Princeton in 1931. A bit later he applied for a patent on a system for generation, long-distance transmission, and utilization of high-voltage direct current. The transmission system, shown in Fig. 2, comprised a large-diameter tubular ground conductor and a smaller-diameter high-potential conductor spaced coaxially with the ground conductor. A high vacuum was maintained for insulating purposes within the hollow ground conductor. The high-voltage electrostatic generator and electrostatic motor were enclosed in high-vacuum cases with direct access to the connecting high-vacuum cable. The generator was similar in principle to the belt generator; it substituted a rotating phenolic disk for the belt as the charge-carrying element and had improved methods for depositing as well as removing the charge from the disk. The electrostatic motor applied the principles of the generator in reverse. The system was designed to exceed greatly the 250,000-volt and 300-mile limitations on A.C. transmission.

A Federal agency about 1933 indicated interest in the direct current transmission system and hopes were raised that it might be made commercially practicable.[7] Since a clear title to the patent was necessary, an examination of the property rights involved was started. Van de Graaff worked on his electrostatic generator while at Princeton as a Fellow of the National Research Council, but he had conceived the invention earlier. After coming to M.I.T., he continued development of his electrostatic generator for work in nuclear physics with a grant from Research Corporation and, at the same time, worked out the direct-current transmission system outlined above. To the latter development, which of the two first seemed to have commercial value,

[5] Eight patents have been issued and two additional applications have been filed.
[6] Figure 1 shows the essential parts of the Van de Graaff generator.
[7] Ref. 39, p. 41 ff.

Dec. 17, 1935. R. J. VAN DE GRAAFF 2,024,957

ELECTRICAL TRANSMISSION SYSTEM

Filed July 5, 1932 2 Sheets-Sheet 1

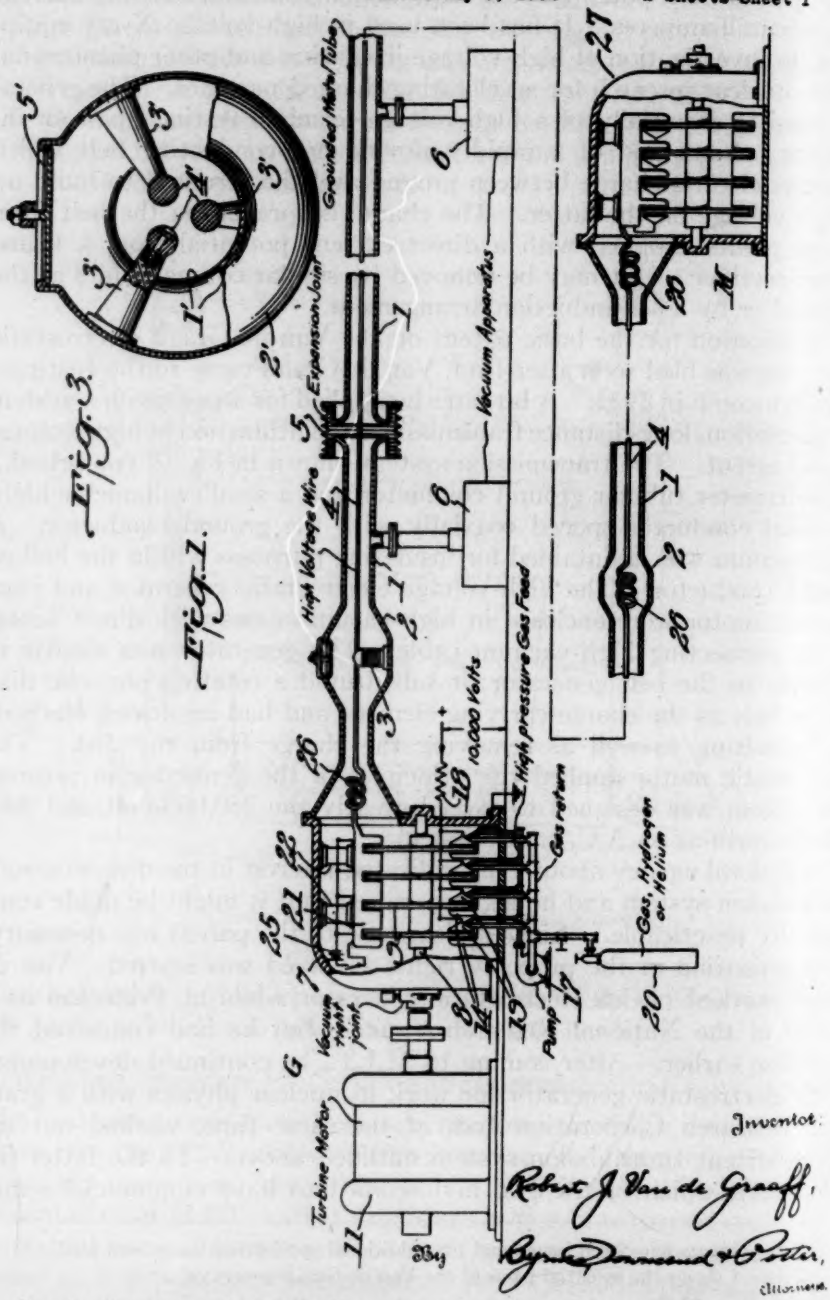

FIG. 2. Patent drawing for the Van de Graaff direct-current transmission system. (From U. S. patent 2,024,957.)

the National Research Council, Princeton, M.I.T., and Research Corporation as well as the inventor had some claim. A contract was prepared to provide for division of proceeds in proportion to the contributions of each party. While it was pending, a difference of opinion arising over whether to give exclusive control to the government in competition with private utilities stopped further commercial development by the government agency. The patent for the transmission system was eventually assigned to Research Corporation, but it has never been used commercially. This case illustrates well the confused equities that may arise in the ownership of university patents.

The development of the high-voltage generator started perhaps less spectacularly, but certainly more steadily, than the development of the transmission system. Dr. John Trump had early become associated with Dr. Van de Graaff at the Institute, and had turned his attention to developing high-voltage X-ray apparatus using the Van de Graaff principle of high-voltage generation. Under Dr. Trump's direction three or more X-ray machines of over one million volts were built for hospitals for cancer therapy.[8] By taking advantage of the high dielectric strength of compressed gases a compact machine with an operating potential of a million volts was built. During the War Van de Graaff directed building of five X-ray outfits of several million volts for examination of heavy munitions castings.

The property rights in the later patents belonged more clearly to the inventors and the Institute than did the rights to the basic patent. The Research Corporation found a fairly great number of licensees for the Van de Graaff-Trump patents. However, in spite of the many licensees, commercialization was slow and royalty returns were insignificant. The few returns were chiefly in the form of flat license fees rather than royalties. Moreover, the royalty fee of 10 per cent of net sales was thought by some to be too high to encourage development. The intervention of the war period soon after this group of patents become available made impossible an adequate trial of the earlier license method. The General Electric Company developed an electromagnetic high-voltage generator of compact size that reputedly could compete with the electrostatic generator for X-ray purposes.[9]

To speed up the commercial development of the high voltage machines, the High Voltage Engineering Corporation, of which Dr. Trump is an officer, was organized within the past two years. The new corporation intends to conduct further developmental research and to manufacture high-voltage equipment. Because considerable expense in development, engineering, and production was necessary for an extended period before High Voltage Engineering Corporation could realize any profits, and because the original inventors held a sizable stock interest

[8] Ref. 36 and ref. 37.
[9] Ref. 37.

in the corporation, all licenses, except a few granted to universities, for the Van de Graaff-Trump patent group were recalled and High Voltage Engineering Corporation received an exclusive license for the limited period of ten years and a non-exclusive license after the termination of that period. The royalty fee is 3 per cent of net sales during the exclusive ten-year period and 2 per cent thereafter.

A further question in this case arises: who shall own further development patents on the Van de Graaff-Trump apparatus that might be made by the High Voltage Engineering Corporation. These developmental patents may be of controlling importance to the commercial value of the high-voltage apparatus. It apparently is felt that the Institute has appreciable property right to these future patents, particularly if an M.I.T. staff member participates in the developments. All future patents for high-voltage equipment assigned to the Institute and Research Corporation go to High Voltage Corporation under the same provisions as those by which present patents are licensed.

The license agreement between Research Corporation and High Voltage Engineering Corporation contains commendable provisions for revocation of the exclusive license in the event the latter corporation participates in any activities which are officially condemned as illegal by the Attorney-General of the United States or the Federal Trade Commission. The agreement also specifies several other practices on the part of the licensee which would automatically invalidate the license:

1. Illegal tie-in sales or tie-in contracts.
2. Illegal blacklisting of potential customers.
3. Combination or agreement with others to fix prices or restrain trade.
4. Failure to use a licensed process if more efficient or less expensive.
5. Failure to serve a geographical area to the best of its ability.

The license agreement is obviously attempting to protect the Research Corporation (and the Institute indirectly) from unfavorable legal action and publicity similar to that which the Wisconsin Foundation received from its exclusive licensing practices. Perhaps a license agreement like this is the solution to the dilemma between maximum patent income and the best interests of the public. The results of this agreement will indicate whether substantial income can be obtained and the public interest preserved by an exclusive license bounded by protective restrictions.

2. *The Milas Vitamin D Patents* [10]

These patents for the preparation of antirachitic substances demonstrate in their administration two special characteristics:

a. These patents in the public health field are often believed to be in a different category from engineering patents. Of course this

[10] Ref. 45.

distinction can be over-emphasized for many engineering inventions, such as the Van de Graaff generator which has been used for X-ray therapeutic purposes, have some application in public health. In a similar fashion, public health discoveries, as the Milas peroxides, may find their chief use in other than the therapeutic applications.

b. These patents now are assigned to and are directly administered by the Institute. They antedate the arrangement with Research Corporation and have thus been handled separately. In their administration they represent early experiments in patent management and, as will be obvious, do not exemplify present Institute patent procedure.

As contrasted with the earlier Steenbock method of irradiating the base substance (perhaps yeast, ergosterol, or milk) with ultra-violet light from an electric arc discharge, Dr. Nicholas A. Milas in 1932 discovered that the activatible substance could be equally well treated by an electrodeless discharge.[11] The ergosterol was introduced into a partially evacuated chamber situated in the field of a high-frequency electric oscillator. The principle by which the Vitamin D activation occurs is not well understood.

In the absence, in the early thirties, of any Institute machinery for patent development, an offer from duPont Company to assume responsibility for the patent administration and to pay royalties was accepted. The patent rights were assigned to duPont, which financed prosecution of the patent application involving interference proceedings.[12] Some royalties were paid to the Institute.

To get the full picture of the situation in regard to Vitamin D, remember that the Steenbock patent controlled a simple and fairly inexpensive process. The Wisconsin Foundation had already, that is before 1932, developed a commercial use for the Steenbock process, and by its licensing policy the Foundation made it both unattractive and legally impossible for the licensee to use a competing patented process, as the Sperti or the Milas process. A memorandum, bearing a 1937 date and written by a duPont executive, is quoted in a published reference cited elsewhere in this paper [13] as stating:

> He [another duPont executive] felt that it would be preferable to deal with the Wisconsin Alumni Foundation since they could be of considerable value to the industry in policing and regulating matters. If, for any reason such arrangements become unnecessary, it would then be possible to consider alternative procedures not involving the use of Foundation patents, that is, we might commercialize the Milas Process.

Although this statement indicates that the Wisconsin Foundation's licensing policy was responsible for the small use of the Milas process, the probable difficulty in producing Vitamin D on an inexpensive, in-

[11] Ref. 45.
[12] *Loc. cit.*
[13] Ref. 1, p. 88.

dustrial scale was apparently a more important deterrent to its use. After the Steenbock process became public property following the court invalidation of the patent, the Milas patent was assigned once more to the Institute. Although one company has taken a license, the Milas process is no longer in extensive commercial use.

This experience points up, in the mind of this writer, the value of Research Corporation in administering university patents in the public interest. Research Corporation could have "insulated" the educational institution from any possible legal or public relations difficulties, while pushing the commercialization of the patented invention as fast as economically possible.

C. *Evaluation of the M.I.T. Patent Procedure*

Research Corporation relieves the Institute of the major part of its procedural difficulties with patents. The advantages of Research Corporation, procedure-wise, have already been noted.

In patent procedure the feelings of the inventor must always be kept in mind. At the Institute both patent committees frequently ask the inventor to express his views in controversial decisions. It has been suggested to this writer that the inventor serve as an *ad hoc* member of both committees while they are considering his invention. The presence of the inventor in each committee while it discussed hotly-contested issues would, however, impair, rather than improve, staff harmony; committee decisions would lose a desirable impersonality. It is better that the committees work in closest touch with the inventor, while remaining impartial juries for controversial questions.

CHAPTER V

AN OVERALL EVALUATION OF PATENT POLICY IN EDUCATIONAL INSTITUTIONS

Two major questions of university research policy, the external problem and the internal problem, were raised in Chapter I. If any single answer to these questions is suggested by the data of the intervening chapters, it is that no patent policy will suit the special needs of all universities, nor perhaps of all departments within a single large university. Patent policy must grow within the climate of each campus; it must adjust itself to the conditions peculiar to each university.

In spite of the natural limitations upon any generalizations, an overall evaluation of university patent policy is in order. Such an evaluation will attempt to judge the merits of patent policy trends as solutions of the external and internal problems of university research.

Two criteria of university patent policies have been applied implicitly throughout this paper and now should be expressly applied. One criterion concerns the public interest which must be preserved and advanced. Society has a stake in the results of scientific research, first, by virtue of the sweeping consequences of invention and, secondly,

by virtue of the social or collective, rather than exclusively individual, nature of the inventive process. "In the realm of organisms all life comes from life, and in social change, including invention, all culture comes from culture; there is no spontaneous generation in either area." So runs the theory.[1] Although this theory of the nature of invention has in recent years been carried to a dangerous absurdity by some jurists to prove that there is no individual invention, and therefore no patent right, it does reinforce the concern of the general public in policy relative to patents.

A second criterion of university patent policy—and it is in reality part of the first—is this: the objectives of the educational institution must be advanced. Because it is a public institution, because it is partially supported either directly by legislative appropriations or indirectly by tax-exemption, a university ultimately shares the objectives of the general public. However, since the end purposes of higher education are more immediate and specific than the indefinite "public interest," this second criterion is a useful and important one.

A. *The Internal Problem*

The relations between the university and its staff in patent matters involves the basic question of division of equities in staff inventions. Deciding the reward to be given the inventor is secondary to that fundamental problem. The right of a university to all patents from research done under its auspices is legally as indisputable as the similar right asserted by the industrial employer. Other factors may make inadvisable complete assertion of this right however.

There are advantages in leaving patent rights to the inventor.[2] He may have more personal interest in pushing aggressively the commercialization of his "brainchild" than would the administrator behind the desk distant from the source of invention. Furthermore, the technical experience of the inventor is frequently important in giving consulting aid to the industrial patent licensees; thus the inventor asks, "why take from me the reins of patent management?" Finally, staff members apparently feel that the freedom from excessive supervision which their research in universities enjoys is a major inducement to lead the academic life. The right to the results of their research, whether patentable or not, is, they argue, part of the academic freedom that differentiates their position in the university from that of the scientist in industrial research.

Offsetting these arguments for letting the staff inventor do as he

[1] Ref. 13, pp. 544–545; ref. 8, p. 421.

[2] The United States Government, which is in many respects in an even poorer position than universities to commercialize patents (ref. 5, pp. 25–28), leaves patent rights to the inventor in many of its departments doing scientific research, reserving to itself only a free, non-exclusive license. The National Advisory Committee for Aeronautics is one such department.

likes with his patents are several disadvantages of such a "hands-off" policy. First, the university inventor seldom has the time or special abilities to be a successful business man. Both the legal protection of a patent and its commercialization are time-consuming and specialized operations. Division of labor is a sound principle in patent management. The individual inventor with a few patents would have difficulty in duplicating the smoothly-working machinery of Research Corporation, or a similar group which can offer an experienced, specialized staff for patent management. Secondly, universities are in a better position to bargain with Big Industry than is the individual inventor. In the third place, and this is the major consideration, it is unfair to place upon a single staff member the responsibility for developing his patent in keeping with public interest and the objectives of the university. Whatever methods he might use in patent management would reflect upon the university with which he was associated. The experience with the Drinker respirator patent at Harvard illustrates a university's involvement in what initially may appear a private matter. It is a university responsibility to decide its research policy.

Although sentiment may argue for complete inventor rights in university patents, practical considerations weigh heavily toward institutional ownership of patents. Some flexibility in dividing equities may permit the best decision in each case. If an inventor demonstrates particular interest in commercializing his invention and if he has the abilities and means at hand for doing so, a patent committee might well consider giving him the "green light" to go ahead on his own. The Institute has, indeed, been the source of small businesses growing from staff discoveries developed by their inventors. The Ruge-DeForest strain gauge may be cited as an example of a staff-commercialized invention. The difficulty in deviating from a fixed policy in dividing patent equities is that inter-faculty relations may be harmed by charges of personal favoritism in committee decisions. For this reason it can logically be argued that a patent committee should attempt no subtle distinctions in equity-division and that all patents made by men on the university payroll should become university property. Such a rigid policy, approaching that applied in industry, but modified to the extent of giving more generous direct reward to the inventor than is customarily given by industry, may best contribute to satisfactory staff relations.

What constitutes "a generous reward" for the inventor is a difficult question. Universities have hit upon no common answer. This writer suggests that, in keeping with an inflexible policy that all patents on inventions developed by staff members belong to the university, a larger percentage of gross returns than the common 7 per cent should be given. The exact figure must be decided upon in light of faculty salaries and policy relative to consulting practices. Probably quite as

important as his financial participation in the patent income is the inventor's feeling of participation in managing "his" patent. To that end the patent committees in doing business in regard to his patent should constantly seek the advice of the inventor.

B. *The External Problem*

The external patent problem, how shall research findings be put to public use, is more difficult to solve than the internal problem. That universities must see that the results of their research come into public use cannot be doubted; that patents are a proper way to encourage such public use is also generally accepted, even by most of those universities which refuse to profit from patents. Furthermore, universities need no longer experiment to find the best mechanism for patent management. The legal and administrative advantages of a non-profit and socially-conscious agency, such as Research Corporation, are firmly established.

A troublesome question remains. To what extent should university patents be pushed as a source of income? The key administrators of each university must answer this question, weighing its financial needs against subtle considerations of public relations. In general in seeking patent income the university is limited by public opinion to giving only non-exclusive licenses. Exclusive licenses may be necessary for social reasons, that is, in order to bring inventions into the widest possible use. However, this device cannot be used to maximize income from patents. Consequently, the only way for a university to push patents for income is by strengthening the administrative methods for patent management. Research Corporation's success in inducing companies to accept non-exclusive licenses and its efficiency in patent management should particularly appeal to a university wishing to earn sizable patent income without legal or public-relations difficulties.

This paper has admittedly proposed no significant solution to the external problem. However, if the alternatives available to the patent administrator are made a bit clearer, if the issues are more clearly drawn by the preceding discussion of actual university experiences, each university may be aided in its individual decision in regard to patent income.

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APPENDIX

SURVEY OF PATENT POLICY IN AMERICAN UNIVERSITIES AND COLLEGES

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside-Sponsored Research	Reward to Inventors	Remarks
University of Alabama[1]	Affirmative	I	A faculty patent committee		"Some percentage" of net profits	$200 spent by Univ. in developing an invention gives patent rights to the Univ.
Alabama Polytechnic Institute[2]	Affirmative	U	Auburn Research Foundation	Flexible policy; up to exclusive license may be given.		
University of Arizona[3]	Affirmative	I	Faculty patent committee and Research Corp.	Written agreement specifies disposition of patents.	7% gross	If inventor chooses not to use Research Corp., he must pay 10% of gross earnings to the University.
University of California[4]	Affirmative	I	Research Corp.		7% gross	From 1926–1931 reports of patentable inventions by faculty members was required; since then, inventions have been left to the inventor, but the Univ. will accept assignment.
California Institute of Tech.[5]		I_e	University Board of Trustees		Most of net proceeds	
Carnegie Institute of Tech.[6]	Affirmative	U	Board of Trustees	License fee remitted to contributing companies until such remissions equal total contributions.		Up to 1943 no control over patents except those from the Coal and Metallurgical Laboratories.
Case School of Applied Science[7]	Affirmative	U	Research Corp.	All patent right reserved to the sponsor.		

N.B. Blanks mean that no information is available.

* *Code for "Patent Ownership."*

I All patent rights expressly left to the *inventor* (subscript "e" indicates that assignment to the university or associated agency is encouraged).

U Rights to patents that are the direct results of the staff member's "regular duties on University time and at its expense" are expressly the property of the *university*.

This appendix is admittedly an oversimplified compilation of many complex points-of-view upon the university patent problem. The inherent limitations of a chart of this type have been pointed out earlier. (*Supra* Chap. II, Sec. C.)

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks

courage).
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This appendix is admittedly an oversimplified compilation of many complex points-of-view upon the university patent problem. The inherent limitations of a chart of this type have been pointed out earlier. (*Supra* Chap. II, Sec. C.)

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks
University of Chicago[8]	Negative—Neither the University or the individual staff inventor may profit from patents.					
University of Cincinnati[9]	Affirmative	I	U. of C. Research Foundation	Patentable results of fellowships go to the donor.		The General Development Laboratory was owned jointly by a food-distributing company and the Univ. Substantial patent profits have accrued to the Univ.
Colorado School of Mines[10]	Neutral (only the Colorado territorial rights are reserved by the School)					
University of Colorado[11]	Affirmative	I		Sponsor may elect to receive all patent rights by paying patents charge of 20% of total costs and inventor fee of 100 dollars.		
Columbia University[13]	Affirmative	I.	University Patents, Inc. and Research Corporation			Original Administrative board was organized to receive Vitamin D patents from a staff member. The staff of the Medical School is forbidden to patent.
University of Connecticut[12]	Afirmative	U	Research Foundation (1945)		At least 20% net	
Cornell University[14]	Affirmative	I.	Cornell Research Foundation, Inc. (1931)	No previous agreement exc. sponsor is assured of "preferential treatment." Exclusive license for short term may be given, exc. for patents from the experiment station.	15% net	Net revenue of "3 or 4000 dollars a year" is reported; exclusive license for the patent life will not be given. The Medical College and its staff do not take patents for profit. Net Income from royalties is returned to department.
University of Florida[15]	Affirmative	U	Faculty Research Council and the Univ. Board of Control	Sponsor may choose among: 1. Free, non-exclusive license. 2. Joint ownership with the University. 3. Full ownership on payment of a patents fee.	At least 25%	Inventor proceeds from thesis patents are divided ⅔ to the faculty member directing the research and ⅓ to the student. Reports of inventions required.

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks
Fordham University[16]	Affirmative	See remarks				For estimated proceeds: a. Less than $6000—left to staff member, who is assessed for overhead plus 10% net fees. b. More than $6000—equity decided by an *ad hoc* committee. Inventor and Univ. *may* divide costs and proceeds 50–50.
Georgia School of Technology[17]	Affirmative	I.	Industrial Development Corporation, Inc. (Private nonprofit)	All rights to sponsor who pays all costs. Fixed agreement with sponsor before research is undertaken.	15 to 33% net proceeds	
Harvard University[18]	Negative	I		Research directors may make their own arrangements with industry.		Neither Univ. nor staff members may profit from patents on therapeutics. Other patents are the private concern of the inventor. Research Corporation administers some public health patents for control, but on a nonprofit basis.
University of Illinois[19]	Affirmative	U	Board of Trustees for policy; Faculty Patent Committee for management	Preferential treatment; title kept by the Univ.	"Liberal share"	Flexible management and policy for patents.
Illinois Inst. of Tech.[20] (Armour Research Foundation)	Affirmative			All rights go to the sponsor.		Large amount of industrial research is done by special research staffs.
Iowa State College[21]	Affirmative	U	Iowa State College Research Foundation, Inc.	Title given to the sponsor; only shop rights kept by the College.	15% net (50% before 1938)	Reserve fund for litigation not to exceed 5% gross receipts.
Johns Hopkins University[22]	Negative (Patent-holding by the university or associated agency considered undesirable.)					The Medical School faculty may not patent; the engineering staff may.

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks
Univerity of Kansas[23]	Affirmative	I_e	Univ. of Kansas Research Foundation	"Preferential consideration" for sponsor—all patent rights in some cases.	At least 15% net	Staff members are under no obligation to assign patents to the Research Foundation. (Kansas State College follows similar policy in all regards.)
LaFayette University[24]		I_e	LaFayette Alumni Research Foundation (1943)			
Lehigh University[25]	Affirmative	U	Board of Trustees	Preferential treatment through prior opportunity to buy or license.	50%	Lehigh Research Foundation does not manage patents.
University of Maine[26]	Affirmative	U		Explicit contract usually gives all rights to sponsor.	"Just compensation"	Policy formed in 1938 in emulation of Penn. State policy.
MIT	Affirmative	U	Patent Committees and Research Corporation	10-yr. exclusive license to sponsor.	7% gross	
University of Michigan[27]	Affirmative	U	The University	Sponsor may purchase patent for additional patent fee of 10% of research costs.		
Michigan State College[28]	Affirmative	U	Faculty Patent Committee and State Board of Agriculture		20% gross	
University of Minnesota[29]	Affirmative	I_e	Univ. of Minn. Research Foundation	In some cases exclusive license given sponsor with royalty for the University.	About 10% net†	Profits from thyroxin patents were used for research in allied fields; such is general policy of the Univ.
Ohio State University[30]	Affirmative		Ohio State Research Foundation (1936)		Adjusted in each case	No fixed policy; each patent and the circumstances leading to it are separately considered.

† The inventor of the thyroxin patent received 10% net; the total net profits were divided equally between the manufacturer and the university.

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks
University of Pennsylvania[31]	Negative (particularly toward medical patents)			Free, nonexclusive license only.		A 1932 policy statement forbade either Univ. or staff member to profit from patents. Later statements narrowed the restriction to public health patents.
Princeton University[32]	Affirmative	U	Patent Committee and Research	Maximum consideration is free, exclusive license in the technical field of the research. ($100 Inventor fee paid by the sponsor.)	7% gross	Special consideration in awarding patent income given to the dept. producing the patentable discovery.
Purdue University[33]	Affirmative		Purdue Research Foundation	Patents rights kept by the Univ.; "small" royalties paid by sponsor.	"Adjusted equitably" (up to ⅓ gross, in cases)	Flexibility in policy and procedures to meet each situation.
Rhode Island State College[34]	Affirmative	U	College research comm.	College and investigator participate in profits, if patent is assigned to sponsor.	Not fixed	
University of Rochester[35]	Affirmative	U	A patent comm. and a patent managing corporation	Variable—up to a free-exclusive license may be given.	"Some share"	
Rutgers University[36]	Affirmative		Endowment Foundation, Inc.		"A portion of net proceeds"	
St. Louis University[37]	Affirmative		Committee on Grants for Research (in School of Medicine)		0 (from theelin patents)	Dr. E. A. Doisy's theelin patents (1930) developed basis for later patent management methods. Comm. on grants administers testing lab.
Stanford University[38]	Affirmative	I	Faculty-administration patent comm.			Drs. Hanzlik and Melutens (1932) assigned Univ. rights to Iodobismitol, a therapeutic agent.

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks
University of	Affirm-	I,	Univ. of Tenn.		"Liberal	Univ. officials directly control Re-

University or College	Policy Toward Patent Income	Patent Ownership*	Agency Used for Patent Management	Policy on Patents from Outside—Sponsored Research	Reward to Inventors	Remarks
University of Tenn.[39]	Affirmative	I$_e$	Univ. of Tenn. Research Corp.		"Liberal reward"	Univ. officials directly control Research Corp. of the Univ.
University of Texas[40]	Indirect profiting	I	Formerly Research Foundation; now Board of Trustees	No special favor given sponsor.	See Remarks	Inventor owns all patent rights, but must pay following portions of net royalties to Univ.: Under 1,000 dollars, net royalties, 0%; 1,000–5,000 dollars, net royalties, 10%; 5,000 up dollars, net royalties, 20%.
Texas A. & M. College[41]	Affirmative	U	Texas A. & M. Research Foundation	Sponsor gets all patents on payment of total costs, plus 20% and $50 inventor fee.	"At least 20% net after paying costs of the research.	
University of Toronto[42]	Neutral	I	Special committees within university	"Preferential treatment as prospective licensee or assignee."	0	No pressure on staff member to assign patent to the University.
Virginia Polytechnic Institute[43]	Affirmative		V.P.I. Research Foundation	Patent rights go to the sponsor paying all costs.	50% net	Virginia Tech. and the inventor are considered to have equal rights in patents from institutional research.
State College of Washington[44]	Affirmative		State College of Washington Research Foundation			
University of Wisconsin[45]	Affirmative	I$_e$	Wisconsin Alumni Research Foundation [separate from (1925) university]		15% net	
Wittenburg College[46]	Affirmative		Wittenburg Research Institute		50% net	Research workers receive no income except from fees from sponsor and from patent profits.
Yale University[47]	Negative		A faculty patent committee and the Yale Corporation (the general governing board)	No standard form. Dep't heads may make own arrangements.		Each patent case is considered individually by the patent committee. Research Corp. used at times.

REFERENCES FOR THE APPENDIX

N.B. p.n.—pages not numbered. "NRC files" will refer to pamphlets and unpublished material in the National Research Council files for the Palmer survey.

1. Ref. 34, p.n.
2. Ref. 41, p. 12; NRC files.
3. Ref. 34, p.n.
4. Ref. 40, pp. 122–3.
5. Ref. 40, pp. 116–7; NRC files.
6. NRC files.
7. NRC files.
8. Ref. 44, Appendix, p. 3.
9. Ref. 44, App., pp. 3–6; ref. 40, pp. 117–9.
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12. Ref. 34, p.n.
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14. Ref. 42, p. 6; ref. 40, pp. 120–1.
15. Ref. 44, App., pp. 7–8; ref. 34, p.n.
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17. Ref. 27, p. 5; ref. 44, App., p. 8.
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19. Ref. 40, pp. 103–4; ref. 27, p. 4.
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21. Ref. 44, App., pp. 10–12; ref. 40, p. 111.
22. Ref. 40, p. 106; ref. 8, pp. 63–66.
23. Ref. 44, App., p. 13; ref. 34.
24. Ref. 44, App., p. 13.
25. Ref. 40, pp. 106–5.
26. Ref. 44, App., p. 15.
27. Ref. 27, p. 5.
28. Ref. 34, p.n.
29. Ref. 40, pp. 113–115; ref. 34, p.n.
30. Ref. 27, App., p. 18.
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34. Ref. 34, n.p.
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37. Ref. 40, p. 101.
38. Ref. 40, p. 125; ref. 27, p. 5.
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40. Ref. 34, p.n.
41. Ref. 34, p.n.
42. Ref. 40, p. 100.
43. Ref. 44, App., pp. 23–6.
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47. Ref. 27, p. 5; NRC files.

THERMODYNAMICS, PART I: THE SECOND LAW FROM THE STANDPOINT OF THE EQUATION OF STATE.

BY

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ABSTRACT.

In this paper the concepts "equilibrium" and "reversibility" are examined from the standpoint of the number of independent variables which define a thermodynamic system. The endeavor is made to show that the number of independent variables which are selected is crucial to the basic concepts as well as to the second law of thermodynamics. If this number is less than the minimum required to define the system completely, the equation of state for the internal energy will be incomplete. It is our practice to employ incomplete equations of state, and this results in processes which we consider to be irreversible. The Kelvin-Planck and Clausius principles are shown to be somewhat related to the first law of thermodynamics, and their validity arises from the fact that the equations of state which are used are incomplete. If these equations were complete, that is, if the number of independent variables were not less than the minimum required to describe the systems completely, we should have complete conversion of heat into work, as well as work into heat. The difficulties in realizing complete equations are considered.

The entropy concept is considered in detail, and it is shown that there are serious limitations in its application.

1. INTRODUCTION.

The following are two fundamental principles which are at the basis of, and sometimes considered as statements of the second law of thermodynamics:

1. Kelvin-Planck principle: It is impossible to devise a system that, operating in a cycle, will produce no effect other than the extraction of heat from a reservoir and the performance of an equivalent amount of work.

2. Clausius principle: It is impossible to devise a system that, operating in a cycle, will produce no effect other than the transfer of heat from a cooler to a hotter body.

In the classic treatment, a Carnot cycle is employed with one or both of the above principles to develop the entropy concept, and it is shown that $TdS \geqq dq$, where dS is an infinitesimal increase in entropy, T the absolute temperature, and dq an infinitesimal quantity of heat added to a system. This expression is usually taken as the mathematical form of the second law. Actual processes taking place in nature are considered irreversible, and the form $TdS > dq$ applies to

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them, whereas for ideal reversible processes the equality $TdS = dq$ will hold. True reversibility, it is considered, is never realized in practice, although under carefully controlled conditions such a process may be approximated very closely.

The second law of thermodynamics presents a view of nature which is unique, for, according to this law, natural processes are asymmetric, entropy always increases, and the available supply of energy for useful work is constantly decreasing. The validity of this law rests on the negation of certain processes, which as a proof is quite different in character from most other basic physical laws. It is for this reason that one cannot help but contemplate its origin and meaning. We may also examine the basis for the validity of the second law, and ask what notion has been introduced, consciously or by implication, in the development which has led to this law. Such are the questions we wish to consider in this paper. We shall limit ourselves to macroscopic states.

2. EQUILIBRIUM AND REVERSIBILITY.

Two terms basic in classic thermodynamics, and which enter even before the introduction of Carnot or any other cycle or process, are "equilibrium" and "reversibility."

The process involved in a Carnot cycle is quasistatic; that is, the system is assumed to be in equilibrium at each stage of the process. We must, therefore, be able to recognize a state of equilibrium before we can consider the performance of a Carnot cycle or any other thermodynamic process. Carnot, himself, must have judged equilibrium by phenomenological criteria. That is, after deciding on the necessary controls or independent variables for the system, equilibrium must have been considered attained when those variables were constant over a period of time. The criteria which we now generally employ for macroscopic systems, such as that state where S is a maximum, E (internal energy) and $F = E - TS$ (free energy), etc., are minima, cannot be considered at this stage because such criteria are *consequences* of our preliminary considerations, and it would certainly be illogical to invoke them at this early stage. We must, therefore, first be able to define our system completely; mathematically, we must have a set of n independent variables, $\alpha_1, \cdots, \alpha_n$ for the system, and this number must be not less than the *minimum* required to completely define all its properties (including internal energy and temperature). *Equilibrium may then be defined as that state where* $\alpha_1, \cdots, \alpha_n$ *are constant with time.*

A "reversible" process, as applied to a thermodynamic system, may be defined as one that is performed in such a way that at each stage of the process any infinitesimal displacement in one direction may be restored by an infinitesimal displacement of the same magnitude in the opposite direction, and in so doing the system and its surroundings are

restored to their original states. This implies, of course, that we know enough about the controls of the system and the surroundings to be able to recognize when we have restored them to their initial states. For example, if the system serves as a medium for transforming heat into work, it is obvious that if we cannot identify the system completely, the latter may retain some of the energy, or lose some of its own energy in the process, and therefore the system and its local surroundings will not necessarily be restored to their initial energy states. Before we can undertake the study of cyclic reversible processes, we must be able to define our system completely. As above, we must have a set of n independent variables, and this must be not less than the *minimum* number required to define completely all its properties. If only $(n - 1)$ variables, say, are accounted for, we can never be certain that the system has been carried through a complete cycle. On examining the $(n - 1)$ variables it may appear to us, for example, that the energy content of the system has been restored to its initial state; but, because of a possible change in the nth variable (which, let us say, has been ignored or of which we are unaware), the system may have retained some energy and the process will not be reversible. Therefore, before we are able to judge whether in a process the internal energy and its other properties have been restored to their original value, we must be able to define the energy for our system by an equation of state

$$E = \phi(\alpha_1, \cdots, \alpha_n) \tag{1}$$

and similar equations for its other properties. The explicit form of ϕ need not be known, but it must be complete as far as the number of independent variables is concerned.

Suppose we are aware of the existence, or use only $(n - 1)$ of these variables in our experiments. In holding these fast, one of two possibilities may arise: (*a*) the extra variable may remain constant when the others are constant; or (*b*) it may be changing constantly or after some time interval. In the first case, even though α_n will have a fixed value when $\alpha_1, \cdots, \alpha_{n-1}$ are fixed, we are not certain that the value of α_n will be the same for different experiments, and E will not be single-valued under such conditions. We will have difficulty in developing an equation of state built on $\alpha_1, \cdots, \alpha_{n-1}$ where E is not single-valued. The problem becomes simple once we recognize and use the extra variable α_n. In previous papers (1) [2] the writer has shown how this may be applied to specific substances, and he has shown that the states resulting from different constant values in the additional variables may be considered like those we usually call "metastable."

The second case may be considered as representing constant instability or instability at a time when α_n changed. At the instant when

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

α_n did change, there will result a change in E, which is very much like that referred to in thermodynamics as a "spontaneous" change.

3. THE ASSUMPTION OF A TWO-VARIABLE SYSTEM.

Realizing the fundamental part which the number of independent variables in the equation of state plays in thermodynamics, let us examine the classic development of the second law. For simplicity we shall consider a closed system (the sum of the component masses to be constant) of a single gaseous or liquid phase. It is commonly assumed that such a system in equilibrium is defined completely by two independent variables, and the equation of state is written in the form $p = f(v, T)$, and $E = g(v, T) = h(p, T)$, etc., where E, p, v, and T are the internal energy, pressure, volume, and temperature, respectively. In other words, a closed single-phase system is said to be in equilibrium if two independent variables are fixed, and this system may be carried through a complete Carnot or any other cycle, provided that these variables are restored to their initial values. Thus we proceed to develop the mathematical form of the second law along classic lines.

It has, however, been generally recognized that certain states are excluded by this assumption. Examples of such states are: (*a*) a stoichiometric mixture of H_2 and N_2 gases free from a catalyst where little or no NH_3 is formed; (*b*) supercooled liquid; etc. Because of the unusual behavior of these states (the writer classes them all as "metastable" states), they are excluded from the thermodynamic considerations at the very outset (2). Later developments in thermodynamics show that such states are not those of stable equilibrium, because they do not satisfy the required conditions that the thermodynamic potential functions be at minimum (or maximum) values. *But the weakness in this argument is that these criteria for stability also rest on the assumption of a two-variable system and therefore cannot rule out states that have been excluded from the very beginning.* We thus see that the classic approach to thermodynamics has been restricted from the very outset.

The basis for the two-variable equation of state would appear to be historical. The early developments in thermodynamics were concerned largely with gases, and we have the work of Boyle, Mariotte, Gay-Lussac, and others who developed the perfect gas law based on an equation with two independent variables. Van der Waals had later developed an improved equation of state, but still with only two independent variables. All subsequent equations retained the basic idea of a two-variable system. It may be safely stated that of the many equations that have been proposed to date, all are of the two-variable type and none has a degree of generality that would permit us to use it for many systems over a large range of pressure, volume, and temperature. Our experimental precision nowadays is far greater than can be accommodated completely by any known rational equation of state based on two variables.

At this point we must not fail to mention the work of De Donder (3) and his co-workers. He did, in a sense, enlarge his equation of state and wrote, for example, for the internal energy of a closed system

$$E = \psi(T, p, \xi) \tag{2}$$

where ξ is the degree of advancement of the chemical reaction taking place within the system. This makes it a three-variable system, similar to those considered by the writer in his previous papers. He has, however, not carried out the full implication of this assumption, but has made the usual fallacy, as we shall illustrate.

De Donder introduces the concept of uncompensated heat, dQ', of the reaction (first used by Clausius) and which is defined by the equation

$$TdS - dQ \equiv dQ'. \tag{3}$$

For an irreversible process, he assumes that $dQ' > 0$; for a reversible process he assumes $dQ' = 0$. He then uses the term A, which he calls affinity and defines it by the equation

$$\frac{dQ'}{dt} = \frac{dQ'}{d\xi} \cdot \frac{d\xi}{dt} = A \frac{d\xi}{dt} \tag{4}$$

where t is the time. De Donder deduces from Eqs. 3 and 4 the following: (1) if $d\xi/dt$ and A are both zero, the system is said to be in a state of true equilibrium; (2) if $A \neq 0$, while $d\xi/dt = 0$, the system is said to be in a state of false or metastable equilibrium. For both types of equilibrium ξ = constant. Obviously his criterion of equilibrium is so designed as to be consistent with the ordinary practice of making S a maximum. In the section of this paper entitled "The Entropy Concept" we shall examine the role of S in the enlarged equation of state, and show the incompatibility in De Donder's assumption.

4. AN ENLARGED EQUATION OF STATE.

In a previous paper (1) the writer considered the reasons why a two-variable equation of state for a closed system is not satisfactory. Consider, first, the perfect gas law. None of the permanent gases satisfies this law to the accuracy of the experimental data over an appreciable range of p, T. There is one characteristic of true gases which is not usually ascribed to a perfect gas, and that is the ability to undergo transformations (liquefaction, ionization, etc.). If such characteristics are to be taken into account, the writer has shown that the equation of state would have to employ more than two independent variables. Any simple system which occurs in nature will have at least one type of transformation. Take the case of helium, to which the perfect gas law applies best. For low enough temperatures this gas undergoes a liquefaction, and for high enough temperatures it may be ionized. A closed system which includes a liquid and its saturated vapor, although

complex from many standpoints, has a single type of transformation and may be treated thermodynamically like dissociation within a single gaseous phase. This has been considered by the writer, and he has shown that in order to satisfy a closed system with a single type of transformation we must employ three independent variables and write the equation in the form

$$E = f(p, x, T) = F(p, v, T) \tag{5}$$

where E and v are the internal energy and volume, respectively, of the entire system, and x the degree of transformation. For a closed liquid-vapor system, x may be defined as the ratio of the mass of the vapor to the total mass of the system. For a single closed gaseous system subject to dissociation, x may be the ratio of the mass of the dissociated components to the total mass. The writer points out that this equation may include "metastable" as well as the ordinary states.

For systems with several types of transformation taking place simultaneously, an equation involving more than three independent variables would be required. Let x_i be the degree of transformation for the ith type within a given closed system; for n distinct types of transformation the equation of state would be

$$E = f(p, v, x_1, \cdots, x_n) = \phi\,(p, T, x_1, \cdots, x_n) \tag{6}$$

and

$$T = \psi(p, v, x_1, \cdots, x_n) \tag{7}$$

where v is the total volume of the system.

The simplest system is one with a single type of transformation, for in nature even the so-called permanent gases have at least one such type. For such a system, write $E = f(p, v, x) = \phi(p, T, x)$ and $T = \psi(p, v, x)$. How will this affect the development of the second law as based on Carnot's cycle? An isothermal will be a surface in a three-dimensional space, and the projection of this surface on the (p, v)-plane will, in general, be an area rather than a single line. Again, the conditions for an adiabatic will be

$$dq = dE + pdv = (\partial E/\partial p)_{v,x}dp + [(\partial E/\partial v)_{x,p} + p]dv + (\partial E/\partial x)_{p,v}dx = 0 \tag{8}$$

which, in combination with $T = \psi(p, v, x)$, reduces the adiabatic to the form $T = f(p, v)$. In the (p, v)-plane this will be an area, and not a single line. We see, then, that to draw a Carnot cycle in the (p, v)-plane of finite area which is to represent a fixed amount of work would have no meaning. Also, Carnot's theorem which states that no engine is more efficient than a Carnot engine when operating between the same temperatures, and its corollary which states that all Carnot engines are equally efficient when operating between the same temperatures, would likewise have no meaning.

5. THE ENTROPY CONCEPT.

We shall consider Carathéodory's work below in the section entitled "Carathéodory's Development of the Second Law." Here we shall examine the formal meaning of entropy and its part in the enlarged system.

The gist of the mathematical form of the second law is that, for a reversible process the quantity dq, although in itself not a perfect differential, has an integrating factor T (or some function of T) such that $dS = dq/T$ is a perfect differential and S becomes a characteristic thermodynamic potential function for the system.

A differential of a function of two independent variables will always have an integrating factor. For a function with more than two independent variables, the existence of an integrating factor is the exception. Considering the difficulties (at least from the classic standpoint) that arise in developing the second law when more than two independent variables are required to define each phase, it is important that we inquire into the potential character of S for such cases. We shall limit ourselves to fluid systems, either a single gaseous phase or a liquid-vapor system. In the latter case we shall neglect the differences in pressure that may exist between the top and bottom of the containing vessel because of the added weight of the liquid. In both cases, we shall assume that the system is in equilibrium, that is, the independent variables which define the system to be constant with respect to time, and we shall assume that the pressure is uniform throughout the system. If within each system the transformation is of a single type, the writer has shown that each may be completely described by three independent variables, such as (p, T, x) or (p, v, T), where x is the degree of transformation, and $v = V/M$, where V is the volume and M the mass of the *entire* system. We may write $E = f(p, T, x) = F(p, v, T)$; and therefore $v = \phi(p, T, x)$ and $x = \psi(p, v, T)$. x may change with a change in v only, when p, T = constant; or, x may change while v = constant, but where p, or T, or both change. Therefore, changes in x need not always be associated with mechanical work; this work must ultimately be accounted for by a change in v only, and for a quasistatic process the mechanical work done by each system will be $W = \int p dv$.

Consider, first, the (p, T, x) space. The first law of thermodynamics requires that E form an exact differential; therefore,

$$\begin{aligned} dq &= dE + pdv \\ &= \left[\left(\frac{\partial E}{\partial p}\right)_{T,x} + p\left(\frac{\partial v}{\partial p}\right)_{T,x}\right]dp \\ &\quad + \left[\left(\frac{\partial E}{\partial T}\right)_{x,p} + p\left(\frac{\partial v}{\partial T}\right)_{x,p}\right]dT + \left[\left(\frac{\partial E}{\partial x}\right)_{p,T} + p\left(\frac{\partial v}{\partial x}\right)_{p,T}\right]dx. \end{aligned} \quad (9)$$

Defining entropy in the usual manner, we have

$$dS \equiv \frac{dq}{T} = Pdp + QdT + Rdx \tag{10}$$

where

$$P = \frac{1}{T}\left[\left(\frac{\partial E}{\partial p}\right)_{T,x} + p\left(\frac{\partial v}{\partial p}\right)_{T,x}\right] \tag{11}$$

$$Q = \frac{1}{T}\left[\left(\frac{\partial E}{\partial T}\right)_{x,p} + p\left(\frac{\partial v}{\partial T}\right)_{x,p}\right] \tag{12}$$

$$R = \frac{1}{T}\left[\left(\frac{\partial E}{\partial x}\right)_{p,T} + p\left(\frac{\partial v}{\partial x}\right)_{p,T}\right]. \tag{13}$$

The following conditions, both necessary and sufficient for dS to be a perfect differential, are that P, Q, R have derivatives, and that

$$\left(\frac{\partial P}{\partial T}\right)_{x,p} = \left(\frac{\partial Q}{\partial p}\right)_{T,x}; \qquad \left(\frac{\partial Q}{\partial x}\right)_{p,T} = \left(\frac{\partial R}{\partial T}\right)_{x,p};$$

$$\left(\frac{\partial R}{\partial p}\right)_{T,x} = \left(\frac{\partial P}{\partial x}\right)_{p,T}. \tag{14}$$

Applying these conditions to Eqs. 11, 12, and 13, we have, on simplification:

$$\left(\frac{\partial E}{\partial p}\right)_{T,x} + p\left(\frac{\partial v}{\partial p}\right)_{T,x} + T\left(\frac{\partial v}{\partial T}\right)_{x,p} = 0 \tag{15}$$

$$\left(\frac{\partial E}{\partial x}\right)_{p,T} + p\left(\frac{\partial v}{\partial x}\right)_{p,T} = 0 \tag{16}$$

$$\left(\frac{\partial v}{\partial x}\right)_{p,T} = 0. \tag{17}$$

Integrating Eq. 17, we find that $v = f(p, T)$, but independent of x, which is a contradiction of our hypothesis that v is a function of p, T, x. Substituting Eq. 17 in Eq. 16 we have $(\partial E/\partial x)_{p,T} = 0$ or $E = g(p, T)$, but independent of x, which is a contradiction of our hypothesis that E is a function of p, T, x. We conclude, then, that dS is not a perfect differential in the (p, T, x) space.

We find also that dS is not a perfect differential in the (p, v, T) space, as follows. Write

$$dS \equiv \frac{dE + pdv}{T} = Pdp + Qdv + RdT$$

where

$$P = \frac{1}{T}\left(\frac{\partial E}{\partial p}\right)_{v,T}; \qquad Q = \frac{1}{T}\left[\left(\frac{\partial E}{\partial v}\right)_{T,p} + p\right];$$

$$R = \frac{1}{T}\left(\frac{\partial E}{\partial T}\right)_{p,v}. \tag{18}$$

The necessary and sufficient conditions for dS to be a perfect differential are that P, Q, R have derivatives, and that

$$\left(\frac{\partial P}{\partial v}\right)_{T,p} = \left(\frac{\partial Q}{\partial p}\right)_{v,T}; \qquad \left(\frac{\partial Q}{\partial T}\right)_{p,v} = \left(\frac{\partial R}{\partial v}\right)_{T,p};$$
$$\left(\frac{\partial R}{\partial p}\right)_{v,T} = \left(\frac{\partial P}{\partial T}\right)_{p,v}. \tag{19}$$

Applying these to Eq. 18, we have on simplification

$$\frac{1}{T} = 0 \tag{20}$$

$$\left(\frac{\partial E}{\partial v}\right)_{T,p} + p = 0 \tag{21}$$

$$\left(\frac{\partial E}{\partial p}\right)_{v,T} = 0. \tag{22}$$

Equation 20 has no meaning. Integrating Eq. 22, we have $E = f(v, T)$ but independent of p which is a contradiction of our hypothesis that E is a function of p, v, T. Integrating Eq. 21, we have $E = -pv + g(T, p)$, which is a contradiction to the integrated form of Eq. 22. Thus, for the (p, v, T) space dS is not a perfect differential.

In a two-dimensional space there is always an integrating factor and T is a particular factor for dq. In the three-dimensional spaces which we are considering here, is there an integrating factor M such that Mdq becomes a perfect differential? Suppose we write for the (p, v, T) space

$$dq = dE + pdv = Pdp + Qdv + RdT$$

where

$$P = \left(\frac{\partial E}{\partial p}\right)_{v,T}; \qquad Q = \left(\frac{\partial E}{\partial v}\right)_{T,p} + p; \qquad R = \left(\frac{\partial E}{\partial T}\right)_{p,v}. \tag{23}$$

The necessary and sufficient condition that an integrating factor exists is that

$$P\left(\frac{\partial R}{\partial v} - \frac{\partial Q}{\partial T}\right) + Q\left(\frac{\partial P}{\partial T} - \frac{\partial R}{\partial p}\right) + R\left(\frac{\partial Q}{\partial p} - \frac{\partial P}{\partial v}\right) = 0. \tag{24}$$

On substituting into Eq. 24 the values of P, Q, R and their partial derivatives as obtained from Eq. 23 and reducing terms, we have

$$\left(\frac{\partial E}{\partial T}\right)_{p,v} = 0 \qquad \text{and} \qquad E = f(p, v) \tag{25}$$

which is a contradiction of our basic hypothesis.

For the (p, T, x) space consider Eq. 9 and write

$$P = \left(\frac{\partial E}{\partial p}\right)_{T,x} + p\left(\frac{\partial v}{\partial p}\right)_{T,x}; \quad Q = \left(\frac{\partial E}{\partial T}\right)_{x,p} + p\left(\frac{\partial v}{\partial T}\right)_{x,p};$$

$$R = \left(\frac{\partial E}{\partial x}\right)_{p,T} + p\left(\frac{\partial v}{\partial x}\right)_{p,T}. \tag{26}$$

The necessary and sufficient condition that an integrating factor exists is that

$$P\left(\frac{\partial R}{\partial T} - \frac{\partial Q}{\partial x}\right) + Q\left(\frac{\partial P}{\partial x} - \frac{\partial R}{\partial p}\right) + R\left(\frac{\partial Q}{\partial p} - \frac{\partial P}{\partial T}\right) = 0. \tag{27}$$

Substituting Eq. 26 in Eq. 27, we have after reduction, the relation that

$$\left(\frac{\partial E}{\partial v}\right)_{p,T} = \left(\frac{\partial E}{\partial v}\right)_{x,p} \tag{28}$$

which is the required condition for integrability.

To examine this equation write $E = f(p, T, x)$ and $v = \phi(p, T, x)$. If p, T = constant, both E and v will be functions of x only, and therefore the left side of Eq. 28 will be a function of x only. If x, p = constant, both E and v will be functions of T only, and therefore the right side of Eq. 28 will be a function of T only. Since we have assumed p, T, x as three independent variables, equating of a function of only x to one of only T is a contradiction.

We may then conclude that there is no integrating factor M which will make Mdq integrable in the (p, v, T) or (p, T, x) spaces.

This answers the point raised above in section entitled "The Assumption of a Two-Variable System" with regard to De Donder's work. He employs Eq. 3 together with S, which we now see are incompatible.

This does not, of course, mean that we have no thermodynamic potential functions in these three-dimensional spaces. In a previous paper (1) the writer has shown the following to meet all requirements:

$$\Phi_\alpha = pvT, \tag{29a}$$

$$\Phi_\beta = pxT, \tag{29b}$$

$$\mathrm{H}_\alpha = E + pv, \tag{30a}$$

$$\mathrm{H}_\beta = E + px, \tag{30b}$$

$$\Omega_\alpha = \frac{E + pv}{T}, \tag{31a}$$

$$\Omega_\beta = \frac{E + px}{T}. \tag{31b}$$

6. THE KELVIN-PLANCK PRINCIPLE.

In the light of the preceding sections, what can be said of this principle? Consider the system as any type of machine, or chemical or biological system, which receives heat at certain intervals from one or several sources and converts it into work (mechanical, electrical, etc.), and at other intervals receives work and converts it into heat.

In order to define completely the internal energy E of the system at each instant during its operation, we must know all its independent variables, say n in number. Let us then write

$$E = f(\alpha_1, \cdots, \alpha_n). \tag{32}$$

If dq is the heat received by the system during an infinitesimal time, and dW the work done on the surroundings by the system during this same time, from the first law we have

$$dq - dW = dE. \tag{33}$$

If the system is carried through a complete cycle, as may be judged by the fact that $\alpha_1, \cdots, \alpha_n$, return to their original values, we have from Eq. 33

$$\oint dq - \oint dW = \oint dE = 0. \tag{34}$$

This states that the net heat received by the system in this cycle is completely transformed into work. If the cycle is reversed, we would have a complete transformation of work into heat. These two processes are permitted by the first law, regardless of whether the cyclic process is isothermal or otherwise, *provided that the cycle is complete. This latter condition is possible only under the condition that Eq. 32 is a complete equation of state, for only then can Eq. 34 be true.* For a fuller significance of these statements let us consider the following.

Let us divide our independent variables into two groups, the first being $\alpha_1, \cdots, \alpha_i$, and the second group being $\alpha_j, \cdots, \alpha_n$. Write

$$\int dE = \int\left[\frac{\partial E}{\partial \alpha_1} d\alpha_1 + \cdots + \frac{\partial E}{\partial \alpha_i} d\alpha_i\right] + \int\left[\frac{\partial E}{\partial \alpha_j} d\alpha_j + \cdots + \frac{\partial E}{\partial \alpha_n} d\alpha_n\right] = \int dE_{\mathrm{I}} + \int dE_{\mathrm{II}} \tag{35}$$

for the sake of brevity. Then

$$\int dq - \int dW - \int dE_{\mathrm{II}} = \int dE_{\mathrm{I}}. \tag{36}$$

Suppose that for some reason we are unaware of, or consciously neglect, the second group of variables, and assume erroneously that $E = \psi(\alpha_1, \cdots, \alpha_i)$ defines the internal energy of the system completely. If we carry through a process where the first group of variables return to their original values, we should conclude that the system has gone through a complete cycle and that $\oint dE_{\mathrm{I}} = 0$. In general, the second group of variables will not return to their original values, so that $\int dE_{\mathrm{II}} \neq 0$. For this false cyclic process we would write from Eq. 36

$$\oint dq - \oint dW - \int dE_{\mathrm{II}} = \oint dE_{\mathrm{I}} = 0 \tag{37}$$

or

$$\oint dq = \oint dW + \int dE_{II}. \tag{38}$$

Let us assume that the temperature T belongs to the first group of variables. Now, if this cyclic process is isothermal, and such that the net heat added to the system is positive, and the net work derived from the system also positive, the Kelvin-Planck principle (which is purely empirical) states that

$$\oint dq > \oint dW. \tag{39}$$

We, therefore, conclude that

$$\int_{q \to W} dE_{II} > 0 \tag{40}$$

where $q \to W$ refers to a process where the net result is that q transforms into W.

Suppose we reverse the path of integration in Eq. 38. Write this as

$$\oint_{W \to q} dW = \oint_{W \to q} dq - \int_{W \to q} dE_{II} \tag{41}$$

where $W \to q$ refers to a process where the net result is a conversion of work into heat. The first integral on the right is the net heat transmitted by the system. All forms of potential energy—electric, magnetic, elastic, chemical, etc.,—which may be set up in the system for a short time but which during the process are ultimately realized as work on the surroundings, will be included in the integral on the left. All other energies which are not recovered as work will be retained by the system and included in the second integral on the right. Some of this unrecovered energy will result in changes in the electric, magnetic, elastic, chemical and other properties of the system, whereas the remainder will be converted into heat. We may write

$$-\int_{W \to q} dE_{II} = \int_{q \to W} dE_{II} > 0. \tag{42}$$

For cyclic processes involving differences in temperature, we must note that the first law permits a complete transformation of heat into work, or work into heat, *provided the equation of state is complete.*

We see then that the Kelvin-Planck principle is not unrelated to the first law of thermodynamics. It is merely an indirect statement of the fact that the equations of state which we use in our thermodynamic considerations are incomplete.

A few illustrative examples may clarify the position that we have taken. Consider helium gas at approximately room temperature and

atmospheric pressure. There will be no transformations (in the macroscopic sense), and the equation of state may be written as $E = f(p, T) = h(p, v)$ or $p = \phi(v, T)$. An isothermal will be a single line in the (p, v)-plane; in going slowly in one direction heat converts completely into work, and in the opposite direction work converts completely into heat. In an isothermal cyclic process

$$\oint dq = \oint dW = 0.$$

If, however, a gas such as NH_3 were used, which is subject to a transformation ($2NH_3 \rightleftharpoons N_2 + 3H_2$), and we restricted its behavior to an

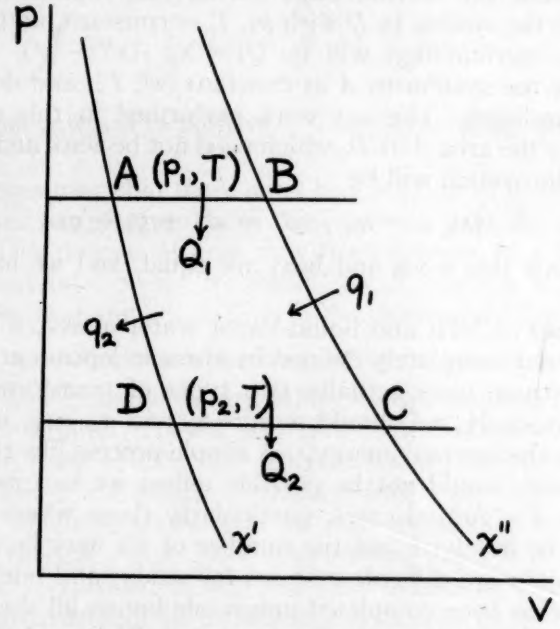

FIG. 1. Family of lines of constant (x, T) in the (p, v)-plane.

equation of state of only two independent variables, we would find that isothermal expansions and compressions at one temperature T would not necessarily lie on the same line in the (p, v)-plane. This is because the dissociation and association processes are not necessarily functions of only p, v. In classic thermodynamics the mass-action law is introduced to make these processes functions of only two variables, but in doing this certain (metastable) states have to be left out. This leaves us in the dilemma considered above in the section on "The Assumption of a Two-Variable System." To overcome this difficulty we should write, for this system, $E = f(p, v, T) = \phi(p, x, T)$ or $x = \psi(p, v, T)$. With T = constant, x will be a function of p, v. Thus we can carry out

an isothermal, cyclic process for this system where $\oint dq = \oint dW \neq 0$. The area $\int pdv$ may, however, be arbitrarily chosen.

Let us next consider a system consisting of the combination of liquid water and its saturated vapor. Such a system may be described by an equation with three independent variables such as given above for NH_3. Referring to Fig. 1, we may draw a family of lines of constant (x, T) in the (p, v)-plane. Starting at A, we may allow the system to expand to B with p_1, T = constant, and the amount of heat received by the system from outside will be $Q_1 = \lambda_{p_1, T}(x'' - x')$, where $\lambda_{p_1, T}$ is the latent heat of vaporization at p_1, T. The system may then be allowed to expand at constant (x'', T) until C is reached. Heat q_1 will be received from the surroundings during this expansion. At C we may compress the system to D with p_2, T = constant, and the heat delivered to the surroundings will be $Q_2 = \lambda_{p_2, T}(x'' - x')$. Finally, we may compress the system to A at constant (x', T), and deliver heat q_2 to the surroundings. The net work performed in this cycle will be represented by the area $ABCD$, which need not be zero, and the net heat received by the system will be

$$(\lambda_{p_1, T} - \lambda_{p_2, T})(x'' - x') + q_1 - q_2.$$

By the first law this work and heat are equal, and we have complete conversion.

In the cases of NH_3 and liquid-vapor water above, if the equation of state were not completely defined by three independent variables, if, for example, there were actually two types of transformation taking place simultaneously, we should require x_1 and x_2, say, in addition to p, T to define the internal energy. A simple process like that along AB where x_1 varied, would not be possible unless we had means for controlling x_2, p, T. Actual cases, particularly those where catalytic reactions may be involved and the number of x's may be much greater than 2, certainly are difficult systems for study, and one cannot state when a cycle has been completed unless one knows all the details of the chemical reactions and the thermodynamics which are involved.

7. CLAUSIUS' PRINCIPLE.

What light may be shed on this principle from the above point of view?

Consider a system operating between two reservoirs A and B at temperatures T_1 and T_2, respectively. Equation 38 applies to any case where the equation of state is incomplete; let us assume that it applies to the present system. If there is a net flow of heat from A to B with the system acting as the medium for this process, then $\int_{q \to W} dE_{II}$ will be positive, which implies that some of the heat of A remains with the system and is not transmitted to B. The work done on the surround-

ings will be given by

$$\oint dq - \int_{q \to W} dE_{II}$$

and will be positive if this difference is positive. If this difference is zero, no work is done, and the process may be considered as pure conduction (including radiation if the radiation pressure is not accompanied by work). Loosely, we should describe this process as taking place "by itself," because no work is involved. From this case, where $\oint dq > 0$ with $\oint dW = 0$, it follows by *definition* that $T_1 > T_2$.

We may, if we desire, add work to the system, that is, make $\oint dW < 0$. In doing so we have from Eqs. 41 and 42

$$\oint_{W \to q} dq - \int_{W \to q} dE_{II} = \oint_{W \to q} dq + \int_{q \to W} dE_{II} < 0 \qquad (43)$$

where the last integral is positive. Therefore, $\oint_{W \to q} dq$ must be negative in this case, meaning that there must be a net flow of heat from reservoir B at the lower temperature T_2 to the reservoir A at the higher temperature T_1. This process of heat flow from a lower to a higher temperature does not take place "by itself," for it requires work to be done on the system from outside. This is the essence of Clausius' principle.

8. CARATHÉODORY'S DEVELOPMENT OF THE SECOND LAW.

We may now examine Carathéodory's work (4) from the light of the above considerations. He has been able to derive the second law in the mathematical form ($TdS \geqq dq$) without the use of Carnot cycle. He employs, however, the classic thermodynamic views, as we see from his Axiom I, in which he states that for each phase of a system, when in equilibrium, there is a function ϵ_i (the internal energy) of the quantities V_i (volume), p_i (pressure), and m_{xi} (the masses of the components). In his general treatment he considers a system of $(n + 1)$ independent variables, subject to the condition that n of these variables are configuration coordinates (v or the like, one volume for each phase). The extra coordinate may be p, which at equilibrium is uniform throughout the system.

Carathéodory rests his entire development on a lemma concerning Pfaffians which is as follows: given a Pfaffian equation (his Eq. 16)

$$dx_0 + X_1 dx_1 + X_2 dx_2 + \cdots + X_n dx_n = 0 \qquad (44)$$

where X_i is a finite, continuous, differentiable function of x_i; if we know that within each region surrounding any arbitrary point P of the space x_i there are points which are inaccessible along the length of the curves which satisfy this equation, then expression 44 above possesses a factor which will make it completely differentiable.

The variables $x_1, \cdots, x_n$ are the configuration coordinates, so that $\sum_{i=1}^{n} X_i dx_i$ represents the work done by the system, leaving the single non-configuration coordinate x_0, which may be a quantity such as pressure. Suppose we find variables in addition to pressure, such as the degree of transformation, to be necessary to define our system completely. The degree of transformation is not, in general, a configuration coordinate, for changes in this coordinate may take place where no work is involved. The system will then be defined by more than one variable of the non-configuration type and the Pfaffian form would be somewhat different from expression 44. We should then have difficulties in developing the second law along the lines of Carathéodory.

A second difficulty exists. In Carathéodory's lemma, the Pfaffian (44) applies to a quasistatic adiabatic change of state for a "simple" system (see his definition on p. 368), which physically is recognized as one which may be subjected to a reversible process. The inaccessible points called for in his lemma lie on paths which are irreversible and cannot be reached from the adiabatic unless work is done. In other words, the lemma calls for the existence of irreversible processes for a system defined completely by the variables $x_0, x_1, \cdots, x_n$. As we have seen above in the section on the Kelvin-Planck principle, if this set of variables defines our system *completely*, we shall have no irreversible processes, and therefore no inaccessible points. Such processes arise, physically, only from incomplete descriptions of a system. Therefore, there is an incompatibility in the basic assumptions of the lemma.

We must, however, grant this fact. If we employ incompletely defined systems, as is always done and if we do not use quantities such as the degree of transformation, an integrating factor for dq, and therefore an entropy function, exists. This, of course, will restrict the application of the second law, and for the very simple system of a single gaseous phase in which dissociation occurs, the entropy function will not be applicable.

9. CONCLUSIONS.

In conclusion, what does the above analysis tell us about the second law of thermodynamics?

First, both the Kelvin-Planck and Clausius principles are essentially statements of the fact that we always use incomplete equations of state, and therefore find certain energy-conversion processes which would be permitted by the first law of thermodynamics to be impossible.

Second, as we learn more about the "controls" of systems, we may expect to realize processes which are more reversible. But it is hardly likely that we shall realize complete reversibility because material systems are highly complex and require very many variables to describe the system completely.

Third, the two principles emanate from the same source, that is, from the fact that $\int_{q \to W} dE_{II} > 0$. This integral, therefore, becomes of very great interest, for it is through this integral that irreversible processes arise.

Fourth, it is the writer's view that the concept of entropy is more restrictive than helpful in giving us an enlarged view of thermodynamics.

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Spores by the Billion.—The "astronomical numbers" of the disease-causing spores that some fungi produce is one reason why plant scientists advise orchard owners to apply protective sprays and thus prevent spores that lodge on the blossoms from developing further and causing infection, according to the U. S. Department of Agriculture.

For example the disease known as brown-rot causes "mummy" peaches: Rot attacks the fruits; they shrivel; some cling; but many drop to the ground. By spring a half-buried mummy peach may develop to five or six cup-shaped fruiting bodies of the fungus. These cups are filled with spores, ready for discharge into the air at about the time the peach blooms in the spring.

A single mummied peach with only three of these cups—called apothecia—may supply spores enough to allow 50 spores to each square inch in an acre of orchard, according to the calculation of John C. Dunegan of the Bureau of Plant Industry, Soils, and Agricultural Engineering.

Dunegan's figuring runs like this: At a recent meeting of Pennsylvania fruit growers he displayed a magnified view of a section of one of these cups. This bit was 1/50 of an inch long and 1/3000 of an inch thick. It contained 275 spores. The spores are too small to be seen without a magnifying glass, and placed end to end it would take more than 2000 of these spores to fill an inch. His specimen came from a typical cup about 2 inches in diameter. Such a cup would contain 150 million spores—more or less. The three cups on his mummy specimen might produce roughly half a billion spores. Infections started by these early spores develop a different type of summer spore and these in turn spread the infection.

These "facts of life" suggest control procedures. One obvious step is to remove as many as possible of the mummies from the trees and from the ground under the trees. In orchards which have had a serious rot problem in preceding years sulfur sprays applied during the blooming period will help reduce the number of blighted blossoms and thus indirectly aid in controlling the disease on the fruit at harvest time. The blossom sprays are, of course, in addition to the regular schedule of spray applications recommended for the control of brown rot, scab and the plum curculio.

R. H. O.

Assembly Line Produces House an Hour. (*Civil Engineering*, Vol. 17, No. 16.)—Automotive mass production methods are now being copied in the manufacture of single- or double-bedroom portable houses equipped with bath and kitchen fixtures, built-in partitions, beds, cabinets and closets, ready for delivery by truck or rail to a home site. Delivered house (priced at $2650 at Wingfoot Homes, Inc. plant, Washington Park, Ill.) can be erected in four hours ready for immediate occupancy.

The quarter-mile-long production line traverses three separate buildings of a reconverted wartime valve factory. The technique employed was developed after two years of pilot operations in the original Wingfoot factory located at Litchfield Park, Ariz.

There is no backtracking of materials. Partial or subassembly sections move forward on dollies along the production-line rails. Overhead units are utilized for lifting floor units and side assemblies and for setting roofs in place. Heavy fork-lift trucks move the finished 3-ton houses to flatcars or trucks. More than 52 homes are in various stages of erection at one time.

R. H. O.

IMPACT BETWEEN CHAIN ROLLER AND SPROCKET IN A CHAIN DRIVE.

BY

R. C. BINDER [1] AND W. V. COVERT [2]

SUMMARY.

This paper presents some analytical relations which may help in developing a better understanding of the mechanics of roller-sprocket impact. Various relative impact velocities are derived. These velocities may be used in impact energy relations for determining limiting sprocket speeds on the basis of roller breakage, noise, heating, and sprocket wear. Some experimental data on roller breakage are presented and used to illustrate a method of organizing data. Impact energy using a certain velocity correlates to some extent with roller breakage.

It is known that the impact between a chain roller and the sprocket tooth has some influence on the performance of a roller chain drive. For example, excessive roller impact may lead to such undesirable conditions as roller breakage, noise, heating, and wear of sprocket teeth. Many successful drives have been developed, and are in operation. There are, however, questions as to just what happens during impact. What are the relations between the variables, and what is the mechanics of the action? Analytical relations might be helpful in correlating experience and in meeting unusual or special cases.

Some analytical work has been presented by Bartlett (1),[3] Clevely (2), and Archibald (3). This previous work, however, does not cover completely the mechanics of impact. The following paper presents some analytical relations not found in the previous literature. These relations might be helpful in developing a better understanding of the mechanics of roller-sprocket impact. Some laboratory results are also given to illustrate portions of the analytical study. There is this major question: what is the relative velocity of impact? This velocity is of concern in setting up an expression for impact kinetic energy. It may be possible to make accurate predictions of roller breakage, noise, heating, and sprocket wear if means are established for accurately determining the impact energy for different operating conditions, as sprocket speed, sprocket size, load on drive, chain tension, and pitch.

Figure 1 illustrates diagrammatically one sprocket (the driver) of a drive, and the chain meshing with the sprocket. After roller *A* has

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[3] The boldface numbers in parentheses refer to the list of references appended to this paper.

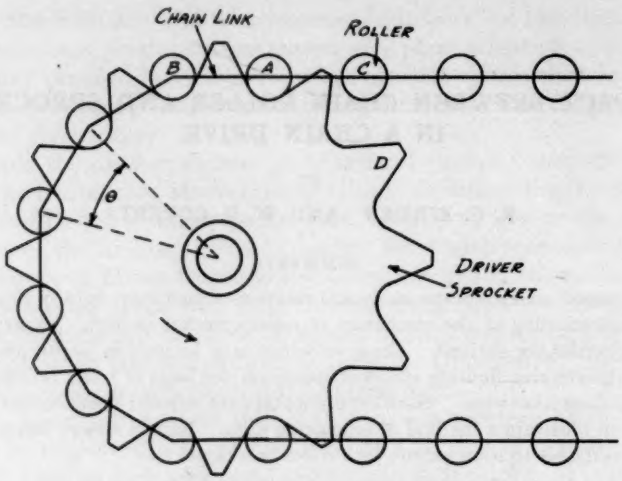

FIG. 1. Diagrammatic sketch of sprocket and chain.

seated on the sprocket, the link connecting rollers A and C starts to turn or articulate, and roller C approaches tooth D. After the sprocket has turned through the angle θ, there has been an impact between roller and sprocket, roller C has seated, and the sequence of events repeats.

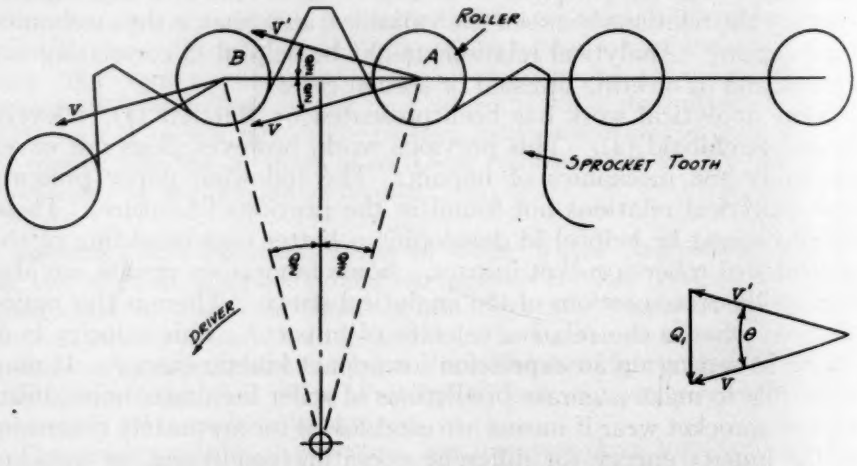

FIG. 2. Positions of rollers for velocity determination.

It will be assumed that the driver and driven sprockets are the same size, that sprocket pitch exactly equals new chain pitch, that the driver rotates at a constant angular speed, and that the strand between sprockets is always parallel to the line of sprocket centers.

The following notation will be used:

N = angular speed of sprocket, revolutions per unit time,
P = chain pitch,
R = radius of sprocket pitch circle,
T = number of teeth on sprocket,
V' = linear velocity of point on pitch line of sprocket, $V' = 2\pi RN$,
θ = $360/T$, angle illustrated in Fig. 1, and
ϕ = theoretical pressure angle, illustrated diagrammatically in Fig. 7.

RELATIVE IMPACT VELOCITY AND IMPACT ENERGY.

Figure 2 illustrates the roller positions for calculating one relative velocity which will be designated as Q_1. This velocity is that between

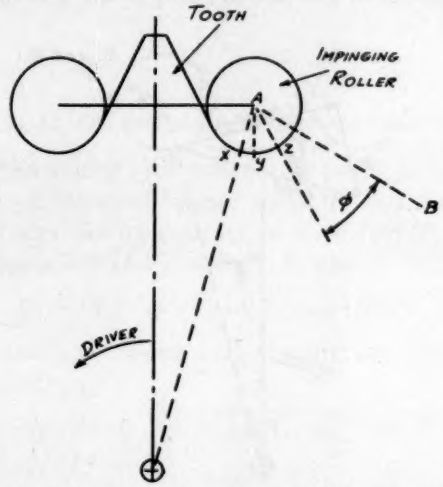

FIG. 3. Points of contact between roller and sprocket.

a roller center and the point on the sprocket pitch circle which will be coincident with the roller center after seating. Consider the state an infinitesimal time interval before roller A seats. The velocity of the center of the roller A has a velocity equal to that of the seated roller B, namely $V = 2\pi RN$. The corresponding point on the sprocket pitch circle has the velocity $V' = 2\pi RN$. The two velocities are equal in magnitude but are different in direction. The velocity triangle in Fig. 2 shows that the vector difference is

$$Q_1 = 2V \sin \theta/2 = 4\pi RN \sin 180/T,$$
$$Q_1 = 2\pi NP. \qquad (1)$$

The relative velocity is directly proportional to pitch and the angular speed of the sprocket; the relative velocity is independent of the number of sprocket teeth. It can be shown that this relative velocity is constant in magnitude during the entire articulation.

The velocity Q_1 is very simple to calculate, and it is very convenient

for purposes of analysis of the impact problem. It is the one which has been generally used as indicated in previous papers on impact. There is a question, however, as to whether or not this velocity applies for all conditions of operation. The following discusses other possible relative velocities, which are velocities between the roller surface and the tooth surface at the point of contact.

There is a problem as to the exact location of the point of contact. The point of contact may be different in various applications because of different conditions of operation. Figure 3 shows three possibilities: point x is on a radial line joining the roller center and the sprocket center; point y is on a line through the roller center which is parallel to the radial centerline of the tooth; and point z is on the line of theo-

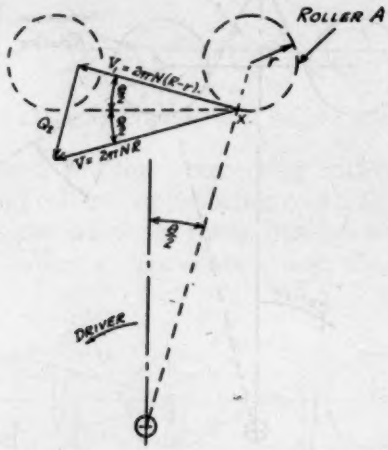

FIG. 4. Relative velocity for contact at point x.

retical tooth pressure. The line AB in Fig. 3 is the polygon chord between centers of the tooth spaces; these centers are on the pitch circle of the sprocket. The measurement of the theoretical pressure angle ϕ is further illustrated in Fig. 7.

It is assumed that, just before seating, the roller does not turn about its own center. For the conditions taken, with the driving strand always parallel to the line of sprocket centers, the resultant velocities of all points on the roller are the same.

Figure 4 shows the velocity vectors for contact at point x. Imagine the state an infinitesimal time interval before roller A contacts. The velocity of any point on the roller before contact is $V = 2\pi RN$. The velocity of point x on the sprocket is $V_1 = 2\pi(R - r)N$ where r is the radius of the roller. Setting up the velocity relations and simplifying gives the final result for the relative velocity Q_2:

$$Q_2 = 2\pi N\sqrt{r^2 + 4R(R - r)\sin^2 180/T}. \qquad (2)$$

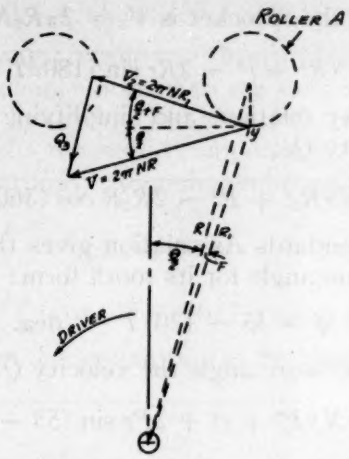

FIG. 5. Relative velocity for contact at point y.

Figure 5 shows the vectors for contact at point y. Imagine the state an infinitesimal time interval before roller A contacts. The velocity of a point on the roller before contact is $V = 2\pi RN$. The velocity V_2 of point y on the sprocket is $V_2 = 2\pi R_1 N$ where

$$R_1 = \sqrt{R^2 + r^2 - 2Rr \cos 180/T}. \tag{3}$$

Setting up the velocity relations and simplifying gives the final result for the relative velocity Q_3:

$$\begin{aligned} Q_3 &= 2\pi N\sqrt{R^2 + R_1^2 - 2RR_1 \cos (360/T + F)}, \\ Q_3 &= 2\pi N\sqrt{P^2 + r^2}. \end{aligned} \tag{4}$$

Figure 6 shows the velocity vectors for contact at point z. The velocity of a point on the roller A before contact is $V = 2\pi RN$. The

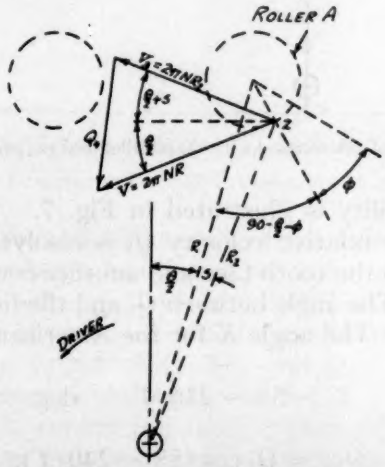

FIG. 6. Relative velocity for contact at point z.

velocity of point z on the sprocket is $V_z = 2\pi R_2 N$ where

$$R_2 = \sqrt{R^2 + r^2 - 2Rr \sin (180/T + \phi)}. \quad (5)$$

Setting up the velocity relations and simplifying gives the final result for the relative velocity Q_4:

$$Q_4 = 2\pi N \sqrt{R_2^2 + R^2 - 2R_2 R \cos (360/T + S)}. \quad (6)$$

The American Standards Association gives the following value for the theoretical pressure angle for its tooth form:

$$\phi = 35 - 120/T \quad \text{deg.} \quad (7)$$

For this theoretical pressure angle the velocity Q_4 has the value

$$Q_4 = 2\pi N \sqrt{P^2 + r^2 + 2Pr \sin (55 - 240/T)}. \quad (8)$$

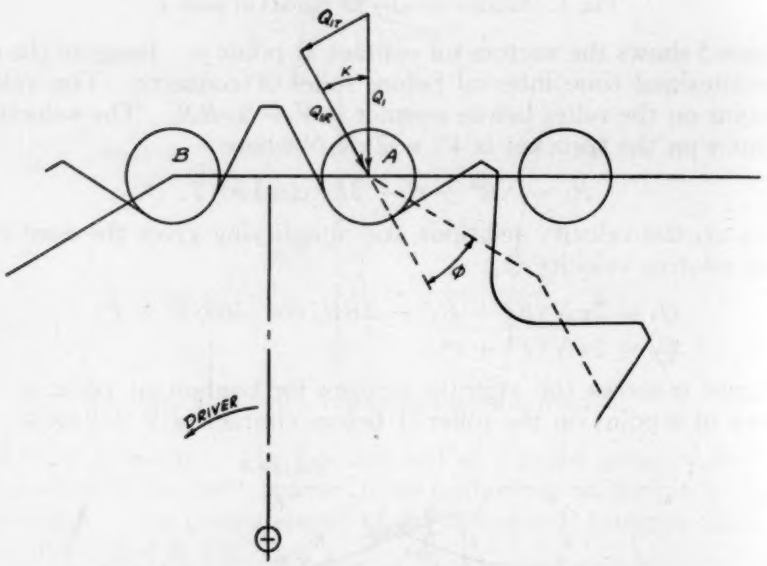

FIG. 7. Components of relative velocity Q_1 parallel and perpendicular to tooth face.

A further possibility is illustrated in Fig. 7. The roller A is just about to seat. The relative velocity Q_1 is resolved into a component Q_{1R} perpendicular to the tooth face and another component Q_{1T} parallel to the tooth face. The angle between Q_1 and the link connecting rollers A and B is 90 deg. The angle K for the American Standards Association tooth form is

$$K = 55 - 240/T \quad \text{deg.} \quad (9)$$

Then

$$Q_{1R} = Q_1 \cos (55 - 240/T). \quad (10)$$

$$Q_{1T} = Q_1 \sin (55 - 240/T). \quad (11)$$

The Q_{1R} component may be called a "destructive" component because it involves a velocity change normal to the surfaces at contact.

Each of the other velocities Q_2, Q_3, and Q_4 can be resolved into a normal component and a tangential component. Using the same notation as for Q_1, the destructive components become:

$$Q_{2R} = 2\pi NP \cos 180/T. \quad (12)$$

$$Q_{3R} = 2\pi NP. \quad (13)$$

$$Q_{4R} = \pi NP \operatorname{cosec} 180/T \, [\cos (35 + 60/T) + \sin (420/T - 55)]. \quad (14)$$

Equation 14 is based on the assumption of the theoretical pressure angle given by Eq. 7.

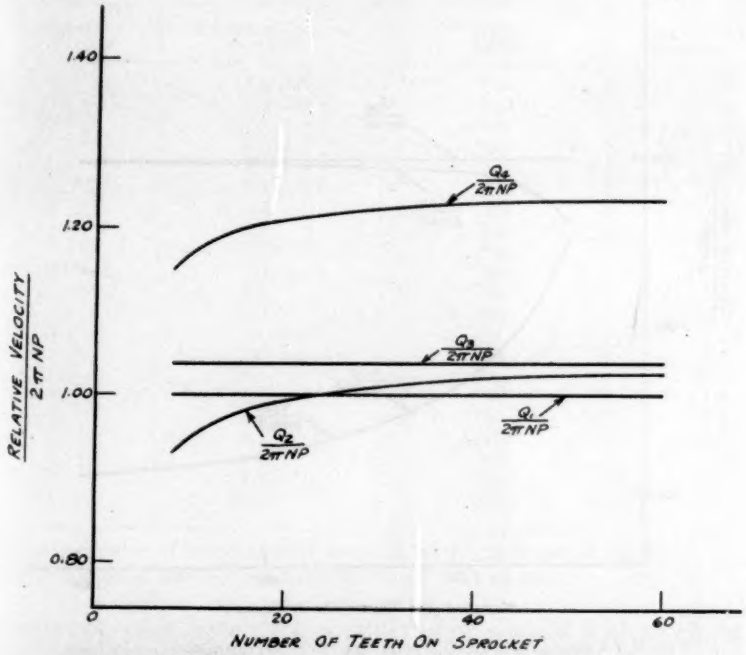

FIG. 8. Comparison of different velocities of impact.

A comparison of the different resultant velocities is shown in Fig. 8 for the American Standards Association tooth form and a pitch of 1 in. The ordinate relative velocity divided by $2\pi NP$ is a dimensionless ratio in any consistent set of units. For some sprockets there is not much difference among the values of Q_1, Q_2, and Q_3. The corresponding destructive components are plotted in Fig. 9.

The impact kinetic energy is $\frac{1}{2}$(mass)(velocity)^2. Let w equal the weight of the impinging body in pounds and g the gravitational accelera-

tion in feet per second per second. As an example, consider the velocity as Q_1 in feet per second. Then

$$\text{energy of one impact} = \tfrac{1}{2}(w/g)Q_1^2 \text{ ft-lb.}$$

Other velocities can be used. It is difficult to say just how much of the mass of the chain is involved in the impact. As a first approximation, it seems reasonable to consider that the average weight of the single link (which is assumed as concentrated at the roller center) is the weight involved. As an illustration, consider a 1-in. pitch chain, American Standards Association No. 80. From about 90 to 93 per cent of the weight of each link is distributed symmetrically about the centers of the rollers.

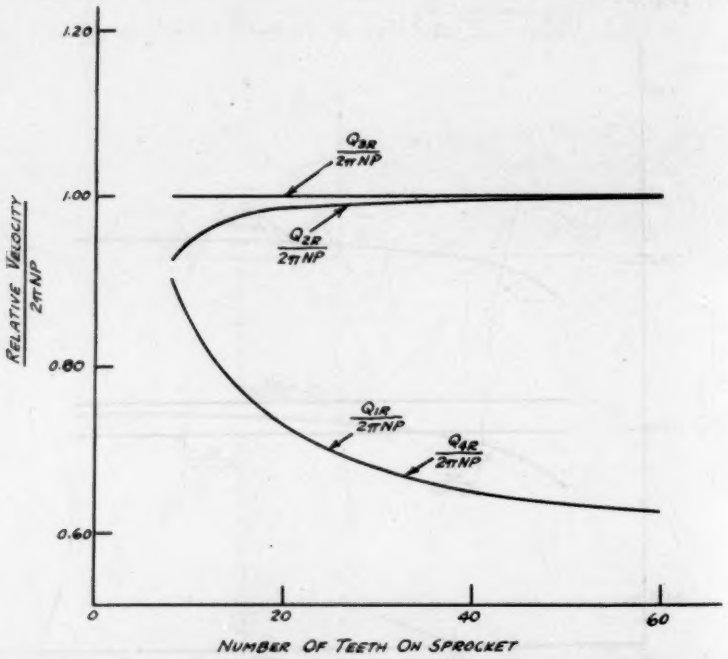

FIG. 9. Comparison of different destructive-component velocities.

The impact energy relation does not consider the effect of chain tension. Since any attempt to include the effect of chain tension would be highly speculative, it was omitted.

For the purpose of capacity rating, the impact energy given on the basis of one of the foregoing velocities can be compared with an allowable impact energy determined by experiment. Such a comparison might be used to determine limiting sprocket speeds on the basis of roller breakage, noise, heating, and sprocket wear. Attempts to reach a conclusion as to what velocity to use in the impact relation for each

particular case are handicapped by a lack of complete information as to just exactly what happens during impact. The foregoing discussion points out some of the difficulties involved. When complete experimental data are available, then some decision may be reached as to just what velocity applies in each case. In the meantime, in regarding roller chain drives, we might well heed the apt expression of O. Heaviside: "Should I refuse my dinner because I do not fully understand the process of digestion?"

LABORATORY TESTS.

Some new data on roller breakage will be presented. These data are helpful in indicating possible trends and methods of organizing and adapting test results.

TABLE I.

Reference No.	Number of Impacts[a] $\times 10^{-6}$	Roller Failure	Coolant Viscosity,[b] Centipoises (100° F.)
1	1.5–3.0	No	1.6
	2.3–3.0	Yes	1.6
2	1.2–1.3	No	1.25
	1.6–2.2	Yes	1.25
	2.1	No	1.6
	7.7	Yes	79
3	1.2	No	1.25
	1.5	Yes	1.25
	1.2–3.2	No	1.6
4	2.3	No	1.25
	2.9	No	1.6
	10.4	No	79
5	3.1–3.3	No	1.25
	2.0–2.2	No	1.6
	28.6	Yes	79
6	1.7	No	1.6
7	1.7–3.1	No	1.6
8	4.1	No	1.6
9	4.0	No	1.6
10	3.3	No	1.6
11	56.0	No	79

[a] Where a number of identical tests were run, the range of impacts is given.
[b] Water = 0.68 at 100° F.; S.A.E. 20 Motor oil = 79 at 100° F.

A series of wear tests were conducted on special $\frac{5}{8}$ pitch chain in the research laboratory of Diamond Chain Co., Inc. In each test the drive consisted of two sprockets of the same size. The drive centerline was horizontal. The top strand of chain transmitted a constant tension in all tests, whereas the bottom strand was slacked as is usual for most drives. All tests were stopped at 1 per cent chain wear elongation (0.006 pin bushing wear per pitch) or 1000 hr., whichever occurred first, as an arbitrary period of duration.

The angular speed of the sprocket, sprocket size, and coolant were varied in these tests; otherwise all drives operated under identical conditions. Some of the pertinent data are listed in Table I. Three

different coolants were used. The number of impacts listed is the number of times a given roller in the chain meshed with the driver sprocket before failure occurred or during the life of the test if failure did not occur. Note that roller failure was found in test references Nos. 1, 2, 3, and 5.

POSSIBLE ADAPTATION AND INTERPRETATION OF TEST RESULTS.

Sufficient and conclusive test data are not available to determine positively the effect of sprocket size, speed, chain pitch, tension, and other factors on roller failure. The limited data, however, show some trends.

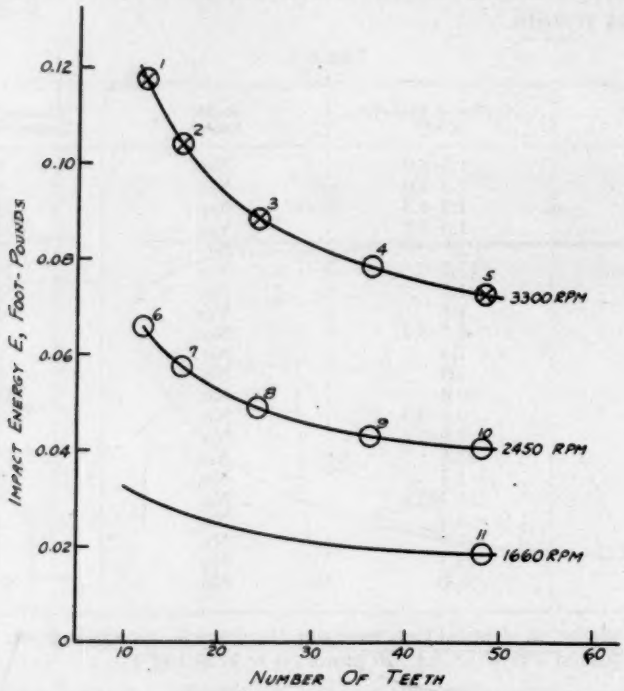

FIG. 10. Impact energy E *versus* number of teeth for $\frac{3}{8}$-in. pitch chain.

Investigation shows that the impact energy E using the velocity Q_{1R}, as given by Eq. 10, gives a factor which might be useful in correlating data. The curves in Fig. 10 show this calculated impact energy E as a function of sprocket teeth for three constant angular speeds of the sprockets. The curves are for the special $\frac{3}{8}$-in. pitch chain. For each constant speed the impact energy decreases as the number of teeth increases. For the same sprocket the impact energy decreases with a decrease in speed. This same general trend for roller breakage has been found in practice, since experience has shown that a sprocket having a

small number of teeth and operating at a high angular speed is destructive to chain rollers. Increasing the number of teeth in the sprocket, while maintaining the same rotative speed, reduces the roller abuse. Thus there is some correlation between the calculated impact energy E and observed roller breakage. This correlation using Q_{1R} in the impact energy is close.

The several points shown by circles in Fig. 10 indicate the sprocket size and speed at which the tests were run. An "X" indicates conditions at which roller fracture resulted; a symbol without an "X" indicates no failures during the test. The numbers at various points on the curves refer to the reference numbers given in Table I.

For this chain one might set a limiting value of about 0.06 to 0.07 ft-lb. for the impact energy E; roller breakage is avoided for impact energies below this limiting value. This limitation, in turn, can be used to establish limiting sprocket speeds.

A number of interesting specific points are brought out by Table I and Fig. 10, as follows:

1. As the number of teeth in the sprocket was increased beyond 24 at 3300 rpm., either the number of failures was reduced or an increased number of impacts to failure was required.

2. Failure of rollers on the 12, 16, and 24 tooth sprockets was eliminated when the speed was reduced to 2450 rpm. This applies only to the results given, which are for a relatively small number of impacts.

3. Coolant viscosity plays an important part in roller impact fatigue. It may be possible that the rate of coolant or oil flow directed at the point of impact is of considerable importance. A comparison of coolant effect is shown in Table I, references Nos. 2, 4, and 5.

4. The effect of chain tension is unknown, since all of the tests were run at the same transmitted chain tension.

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(2) S. E. CLEVELY, "The Action of Chain Gearing," *Machinery* (London), Vol. 32, No. 828, August 23, 1938, p. 657.

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S. E. CLEVELY, "The Application of Chain Gearing," *Ibid.*, Vol. 35, No. 888, Oct. 17, 1929, p. 73.

(3) F. R. ARCHIBALD, "Energy Losses in the Chain-Belt Problem," *Mechanical Engineering*, Vol. 68, No. 2, Feb., 1946, p. 139.

Fundamental Properties of Metals. (*Electrical Engineering*, Vol. 66, No. 11.)—Although great progress has been made in obtaining a sound general knowledge of the forces that hold matter together, scientists up to now have not been able to extend this work to three important classes of materials: the complex substances such as proteins that constitute living organisms; atomic nuclei; and metals and alloys; according to Professor Linus Pauling, director of the Gates and Crellin laboratories of chemistry at the California Institute of Technology.

Speaking before the Southern California section of the American Chemical Society, he pointed out that application of a recently formulated equation has indicated that metallic atoms are bound to one another by electrons which they share. A similar mechanism provides the binding forces that govern the mechanical properties of organic materials such as fats and wood.

Interpretation of metallic structure in accordance with the new equation provides a qualitative explanation of many of the properties of some of the most common metals. It is found that atoms of chromium, tin, and manganese exist in two forms, small atoms with high combining powers, or valences, and large atoms with low valences, and in many metals each atom is attached to some of its neighbors by strong bonds and to others by much weaker links. The association of metallic valences with interatomic distances and properties of crystals has led to the construction of a reasonably satisfactory theory, however the whole treatment is essentially empirical in nature.

R. H. O.

New Process Forecasts Wider Use of Titanium. (*Compressed Air Magazine*, Vol. 52, No. 9.)—Pilot-plant operations at Boulder City, Nev., by the U. S. Bureau of Mines may lead to a wider use of titanium, which is described as a light metal of exceptional chemical and physical properties. Ductile in the pure state so that it can be fabricated and worked, it is said to be superior to aluminum and magnesium on the basis of strength and weight and to possess many of the valuable properties of stainless steel. However, it has been difficult to produce in the pure state, and that has limited its industrial application.

By the new process developed by the Bureau of Mines, pure titanium chloride is dripped onto molten magnesium in the presence of helium under slight pressure. The mixture thus obtained is wet-ground, screened, and leached with dilute hydrochloric acid, yielding a power that is pressed into briquettes and sintered at 1830° F. under a high vacuum to remove the hydrogen picked up during leaching. The sintered material, it is claimed, can be rolled at room temperature with reductions of 20 per cent. before annealing, or of as much as 75 per cent. at 1200° F. Output of the pilot plant is about 100 pounds of pure titanium a week.

Though cost of production by the improved method is still relatively high, the expectations are that large-scale operations will effect some economies. Be that as it may, the simplified reduction furnace promises to make pure titanium available for uses where its favorable properties outweigh price and for the manufacture of airplane parts; diaphragms that are maintained under tension; spindles, spools, and other working components of textile machinery; certain types of springs; and other products where lightness, strength, and resistance to corrosion are vital factors.

R. H. O.

PLANETARY PROPERTIES OF FAST CARS.

BY

A. F. ZAHM,[1] Ph.D.

PREFACE.

In past decades many inventors and writers have advocated designs for super-speed travel round the earth or through cosmic space. One scheme is a vacuum tunnel girdling the globe or a wide continent. Inside it a car speeds many thousand miles an hour suspended by magnetism to avoid mechanical friction. Another scheme is the space car, rocket-driven many miles a second, for journeys round the earth or moon, etc. Both kinds of craft naturally must have air constantly refreshed, as in a submarine.

As such projects are likely to allure men for indefinite future years, it seems worth while to appraise some basic properties of the high-speed car, which always exist and at times may prove dominant. The mass is independent of locality. Also the earth's speed round the sun and his round the Milky Way, though both enormous, can here be ignored as unfelt by mundane vehicles.

WEIGHT AND BUOYANCY.

At any altitude the weight of a body equals its mass times the local intensity of gravity. This latter is given by

$$g/g_0 = R_0^2/R^2 \qquad (1)$$

where g is the intensity at the distance R from the earth, and g_0, R_0 like values near the earth.[2] Assuming in turn $R/R_0 = 1, 1.001, 1.002$, etc. gives by Eq. 1 the weight values in Table I.

Thus the loss of weight is shown to be 0.5 per cent at 10 miles height, and 9.3 per cent at 200 miles, say just above the atmosphere. For a

TABLE I.—*Relative Weight and Buoyancy at Various Altitudes.*

Altitude R, miles	Relative orbital radius, R/R_0	Relative gravity, $g/g_0 = R_0/R^2$	Weight of 50-ton airplane, lb.	Loss of weight, lb.	Relative atmospheric density, ρ/ρ_0	Buoyancy loss, per cent
0	1.000	1.0000	100,000	0	1.0000	0.00
4	1.001	0.9980	99,800	200	0.5517	0.4494
8	1.002	0.9960	99,600	400	0.2655	0.7356
10	1.0025	0.9950	99.500	500		
40	1.010	0.9804	98,040	1,960		
200	1.050	0.9070	90,700	9,300		

[1] Chief (Retired), Division of Aeronautics, Library of Congress, Washington, D. C.

[2] In elementary mechanics some write $R_0 = 4000$ miles, $g_0 = 32$ ft. per second per second.

transport plane 4 miles high the loss is 0.2 per cent of the gross weight, or say 0.4 per cent of the useful load. This gravitational loss is offset by a loss of about 45 per cent of the sea-level buoyancy. The latter is negligible, especially for a metal plane. For example, the sea-level buoyancy of a ton of aluminum is less than 1 lb., or 0.05 per cent.

RADIAL ACCELERATION.

In normal flight with speed v an avion's acceleration is

$$j = v^2/R \qquad (2)$$

away from the earth's center, distance R. Here v is referred to a fixed origin at the earth's center, not on the earth's surface.

In mile-second units Eq. 2 can be written

$$j = v^2/4000, \text{ miles per second per second} \qquad (3)$$

and in foot-second units it can be written easily but less simply.

From Eq. 3 one notes that if v is one mile a second, $j = 1/4000$ mile per second per second, or roughly 4 per cent of g at sea level. If v is 1/5 mile a second, j is 1/25 or 4 per cent of g. If v is 5 miles a second, j is 25×4 per cent of g; *viz.* the radial acceleration equals that of gravity. Of these last two examples the first indicates that present-day cars and planes feel no great loss of weight by centrifugal force; the second that a planetary car is apparently weightless at 5 miles a second, and therefore could revolve as an earth satellite permanently without continued propulsion. This alluring fact has been known many decades, even centuries.

Some visionaries foresee craft circling the earth at 100,000 mph. But then the radial acceleration must exceed 30 g. What agent will hold the craft down to a circular orbit? [3] What will save the passengers from pancaking against the ceiling? Or shall car and content hurtle away indefinitely? At one fourth that speed bodies out-climb the earth's gravitation.

For a point fixed on the equator $j = 0.003\ g$, by Eq. 3, since there $v = 1000$ mph. roughly. That is, the inertia lift on a resting plane at the equator is about 0.3 per cent of its weight. Now if the plane skims eastward at an additional speed of 1000 mph., its whole speed is 2000, and inertia lift 1.2 per cent; but if it skims westward at that rate, its whole speed is $v = 0$, and its inertia lift is zero. In said eastward motion a 100-ton plane would have 1800 lb. more centrifugal lift at full speed than when at rest.

By similar reasoning these two cases can easily be generalized to disclose the inertia lift of craft having any speed and direction at any

[3] Shall the centrifugal force, 30 mg., be balanced by the weight and −29 mg. by downward impact of the tenuous air? This negative lift must be 290 tons for a 10-ton vehicle. A nice problem in aircraft design!

place on earth. A table and graph of such values might be serviceable. (Fuller treatment appears in *Aviation* for March, 1945, page 183.)

KINETIC ENERGY AND COST.

A mass m with speed v has the kinetic energy

$$E = mv^2/2.$$

Thus at 1 mile a second each pound has the kinetic energy

$$E = (5280)^2/2g = 660^2 \text{ ft-lb.}$$

This equals $660^2/33{,}000$ horsepower minutes, or 0.22 horsepower for 1 hr. At 5 miles a second the last figure becomes $25 \times 0.22 = 5.5$ horsepower hours for each pound mass of the planetary car. That is 11,000 horsepower hours per ton.

At this rate a 10-ton planetary car, rounding the earth just above the atmosphere, would have a kinetic energy of 110,000 horsepower hours, costing at least $10,000. This equals $1,000 each if the mass includes 10 passengers. If they stayed for a hundred trips round the world, the cost of each would be $10 a trip for power, since the energy needs no renewal.

By contrast, one notes that earth riders swing round the sun annually at no mileage cost. A billion stars course the Milky Way free of charge. It is the first cost that counts. At 30 miles a second a pound of meteorite has 36 times the energy above computed, or 198 horsepower hours. That equals nearly a month's toil of a big draft horse. Meteorites come high! The sun sweeps round the Milky Way at 180 miles a second; six times the assumed meteorite speed, involving 36 times the energy per pound, or the output of a draft horse for nearly three years.

CONTROL PROPERTIES.

A space car passively circling the earth outside the stratosphere would retain constant speed of translation and rotation. For it would lack resistance to either motion. The spin velocity could have any magnitude or direction. If desired, some portholes could look always along the earth's radius. Through these an observer would behold the earth's main features sweep past about 300 miles per minute. At 5 miles a second each round trip would take about 1.4 hr. Boston to the antipodes, 0.7 hr.; antipodes back to the world's hub, 0.7 hr.!

The car's normal poise could be adjusted by simple means minus rudders or issuing jets. To turn it positively about an axis some contained smaller body could be turned negatively, thereby generating an opposite reaction able to start the car turning positively. The smaller body, for example, might be the armature of an electric motor. The angular momentum begot in the massive car would be equal and opposite to that of the small armature. Both could be continued for a

while; the car turning quite slow, the armature quite fast. Stopping the motor at the right instant would stop the car's induced displacement at the desired amount.

This principle is employed by a falling cat to land upright, and is proved experimentally by dropping a wooden cat designed to do the same. A good proof can be given with a closed iron box quite free to yaw, enclosing a motor with axis vertical. Running the motor yaws the box; stopping it stops the box but leaves its yaw displacement fixed. Whether still or rotating, their added momentum is zero; for the closed box prevents the armature from gripping external air or earth's magnetism. For linear motion a like principle obtains, as is well known.

LIFE WITH COUNTERACTED GRAVITY.

The assumed planetary car, suitably pressurized and circling with contents uniformly round the earth, just outside the stratosphere, would appear to be weightless, due to radial acceleration. Furniture and passengers would float freely unless somehow anchored or magnetically shod. Fish could pause or swim in the air very much as aquatic ones in sea or lake . . . etc. etc.

A man could pose in any attitude, erect or inverted. With closed eyes he would be unconscious of direction. He could stand on the ceiling, side walls or floor indifferently; or shuffle about with magnetic soles. Chairs, beds, etc. would be superfluous. Invalids could rest day and night without fatigue, insensible of gravity pressures internal or external; a delightful prospect for heavy terrene patients weary from prolonged reclining.

SUNDRY SATELLITES.

Keen astronauts expect to launch space craft set to circle the globe perpetually. If clustered they may appear luminous at dawn or dusk, crossing the sky like a swift star, or a star chain if duly aligned, or a string of moonlets; who shall say? Astronauts are lavish, not bearing the cost of wanted empyrean splendors.

Our moon is roughly 2000 miles across and 240,000 miles away. Hence a moonlet could show as big a face if 240 miles from us and 2 miles across, or a nice little face if 1000 feet across. In this case a few thousand V-bombs could compose the cluster. Or they could emit a trail of snow or white sand to create a moonlet, and return home for more. In due time they should put elegant rings round the earth rivalling Saturn's, yes?

HEAT AND PRESSURE AT STAGNATION POINTS.

An air current sweeping over streamline craft heats their exposed surface by friction and compression. At stagnation points, where the flow comes to a full stop, the friction is null; the compression and temperature rise is calculable by established formulas. At these points the

compression and heating are greatest. Such hot spots may be at the nose or near the front wing edges of aircraft. The calculated pressures and temperatures may be tabulated for convenient reference.[4]

For adiabatic compression of common air on coming to rest from the speed v of a level stream at the initial pressure and temperature p_1, T_1, textbooks give

$$T_2/T_1 = (p_2/p_1)^{2/7} = 1 + nv^2$$

where T is the absolute temperature, p absolute pressure, n a well-known coefficient.[4] For sea-level U.S. standard air $T_1 = 518.4°$ F., and for full impact pressure at speeds up to 1000 miles an hour $n = 0.345259$. Then the temperature rise is

$$T_2 - T_1 = T_1 n v^2$$

where $T_1 n = 0.000179$, the product of the above numbers. Thus at the hot spots the temperature rise increases as the square of the stream speed, as shown in Table II. The pressure rise there given is taken from the cited paper.[4]

TABLE II.—*Increase of Pressure and Temperature of Sea-Level Air at Stop Points.*

v, mph.	100	200	400	600	800	1000
p_2-p_1, lb. per sq. ft.	25.69	104.09	438.33	1,073.0	2,140.6	3,860.4
T_2-T_1, deg. Fahr.	1.79	7.16	28.64	64.46	114.56	179.0

The table shows that at stagnation points moderate airplane speeds beget perceptible but not baneful increments of pressure and temperature. The highest present-day speeds show increments that invite the attention of designers. Still higher speeds of travel demand special provisions against excessive impact pressure and heating.

For such higher speeds the present formula gives excessive pressure. For $v > 4a$, Rayleigh finds $p_2/p_1 = 1.30v^2/a^2$, a being the speed of sound in the unchecked stream. Thus $T_2/T_1 = (1.3v^2/a^2)^{2/7}$. From these equations we derive Table II extended, where $p_1 = 2{,}116.8$ lb. per sq. ft. $- 1{,}058$ tons per sq. ft.

TABLE II. *Extended.*

v/a	4	8	12	16	20	24
p_2-p_1, tons per sq. ft.	20.95	86.97	197.1	351.04	549.1	729.18
T_2-T_1, deg. Fahr.	715.44	1,315.08	1,793.09	2,206.10	2,576.66	2,936.47

The values in the table apply to some rocket missiles and some projected airplanes. At four times the speed of sound the nose tem-

[4] A. F. Zahm and F. A. Louden, "Tables for Pressure of Air on Coming to Rest from Various Speeds," NACA Report No. 316, U. S. Government Printing Office (1929).

perature jumps over 700° F.; the nose pressure over 20 tons per square foot. A few materials can withstand both increments. But no material can endure the two increments listed in the last column. There the speed is roughly 5 miles a second, or that of the touted man moon circling just beyond the stratosphere. Obviously then if such moon bucked common air it would suffer both intense heat and mechanical rupture. Far more severe would be the heat and stress in the visionary jet plane cleaving the troposphere at 100,000 mph.

The values so far obtained are for stagnation points. Further equations and tables are needed for the distribution of velocity, pressure and temperature at other points of practical surfaces. For some geometric figures and flow conditions valid formulas and tables are available. Further researches are under way, especially with missiles and with models in high-powered wind tunnels. Both means can attain speeds many times that of sound, even ten times at present. Thus likely stagnation injuries can be foreseen and obviated. Ample references are given in von Kárman's supersonic bibliography.[5]

[5] *Journal of the Aeronautical Sciences*, July, 1947, p. 398.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

DIAMONDS USED TO DETECT ATOMIC RADIATION.

Radioactivity studies conducted by Dr. L. F. Curtiss of the National Bureau of Standards have shown that diamonds are highly sensitive to gamma rays and may be used to detect this radiation in the same way as a Geiger-Müller counter. It has been found that a diamond placed in a strong electric field initiates sharp electrical pulses when gamma radiation is absorbed, and, as with a Geiger counter, a count of pulses gives an indication of the intensity of the radiation. The diamond counter has not yet been tested for beta radiation, but it is expected that a similar effect may be observed in this case.

Gamma rays—electromagnetic rays of very short wave length similar to X-rays—are constantly given off by radioactive materials. Of great value in many lines of research, they are used principally in medicine for treatment of malignancies, in industry for the radiographic examination of metallic castings, and in nuclear physics for the study of the structure and energy levels of the nucleus. The development of the diamond counter is expected to provide an important tool for scientists and technicians in these fields.

To use a diamond as a counter, it is clamped between two small brass electrodes maintained at a difference in potential of about 1,000 volts. When a source of gamma radiation is brought within range of the diamond, there occur across the electrodes pulses of current, which after amplification may be detected and counted on any suitable indicating device, such as an oscilloscope, a current meter, a set of earphones, or a loud speaker. In the apparatus assembled at the Bureau, primary amplification is effected with minimum loss of original intensity through the use of a triode very close to the diamond in the circuit. The output from this tube is then applied to a two-stage amplifier, from which pulses of sufficient magnitude are obtained to operate the detecting instrument.

The pulse-producing property of the diamond is thought to be a result of its highly symmetric crystalline structure, characterized by a very regular arrangement of carbon atoms with relatively large intervening spaces. According to this theory, when a photoelectron is emitted by a diamond atom as the result of the absorption of gamma radiation, the freed electron is accelerated through the interatomic space toward the positive electrode. Within a very short distance it

* Communicated by the Director.

acquires such high velocity that other atoms along its path are ionized by collision with the release of additional electrons, which in turn are accelerated in the same direction. This multiplication of charges repeats itself in rapid succession, producing a sudden avalanche of electrons equivalent to a small pulse of current. The larger the diamond the more electrons would be involved in the sudden pulse that is counted. This means that the gamma-ray sensitivity of a diamond counter should be proportional to the size of the crystal. However, adequate sensitivity is obtained with a comparatively small diamond. Apparently the diamond quickly recovers from its ionized state, as the pulses registered are extremely sharp. The diamond counter is thus a very "fast" counter, capable of indicating a much greater number of pulses per minute than is possible with the ordinary Geiger-Müller counter.

Similar principles have been utilized at the Bell Telephone Laboratories in experiments with alpha particles. Here, because of the poor penetration of this radiation, both electrodes were applied to the same crystal face, and the impinging particles were detected by means of the surface ionization they produced.

While gamma rays may produce photoelectrons in other crystalline substances such as sodium chloride, in most cases the crystal must be cooled to a very low temperature to eliminate background noise, which may be due to continuous ionization of the lattice at ordinary temperatures. The diamond is the only material so far investigated that performs satisfactorily at room temperature.

Industrial diamonds used as counters must be colorless and absolutely free of flaws; about one diamond in forty meets these specifications. Apparently color in a crystal, such as a diamond, indicates a change in the relation of outer electrons to atomic nuclei. Such a condition might tend to inhibit the generation of the required electrical pulse. Obviously, a flaw in the diamond would impede a surge of electrons through the affected portion of the crystal.

Diamonds tested in the Bureau's laboratories have been found to have a sensitivity per unit volume equal to or greater than that of any counter constructed by man. One of these diamonds, measuring about $\frac{1}{8}$ inch on each face, has approximately the same sensitivity for gamma radiation as a laboratory-constructed Geiger-Müller counter of the usual type. Many diamonds are larger and would thus be much more sensitive.

The conventional radiation counter lasts from three months to two years, depending upon how much it is used. A diamond counter, on the other hand, is practically indestructible, although extremely long use might produce discoloration or flaws, with a corresponding loss in sensitivity. There is no appreciable cost difference between the diamond and an ordinary counter. However, one of the important advantages of the diamond counter, in addition to sensitivity and long

life, is its small size, permitting use inside the human body or in small openings in industrial equipment.

Alpha, beta, and gamma radiations are important manifestations of the nuclear changes occurring in the disintegration of radioactive isotopes. Prior to the development of the atomic pile, radio-isotopes were produced in limited amounts in the cyclotron and other "atom smashers." Now, however, they are obtained from a chain-reacting pile cheaply and in quantities sufficient for extensive use as tracers in medical, biological, and industrial research. Basic to the use of a radio-element as a tracer is the sensitive detection of the presence of such an element by means of the radiation it continually emits. The detection of radioactive emissions is also important in experiments involving nuclear radiation, transmission and disintegration, as well as in safeguarding the lives of those engaged in these projects.

The presence of extremely minute quantities of radioactive material may now be determined by means of the Geiger-Müller counter, one of the most sensitive of scientific instruments, but an increasing demand has resulted in a critical shortage of such equipment. For this reason, many laboratories have found it necessary to construct counters for their own use. In view of the relative abundance and moderate cost of industrial diamonds, as well as the simplicity and apparent indestructibility of the diamond counter, it is probable that Geiger-Müller counters may be replaced by diamond counters for many applications.

COSMIC AND SOLAR RADIO NOISE.

Scientists at the National Bureau of Standards are initiating a project for the observation and analysis of radio noise generated by the sun, a companion project to cosmic radio noise studies already in progress. The new investigation will seek to determine the range of frequencies broadcast from the sun, received intensities, and the correlation of solar noise with other solar, interstellar, and terrestrial phenomena.

Two giant radar mirrors at the Bureau's radio propagation laboratory at Sterling, Virginia, will intercept and record solar noise reaching the earth. These devices are particularly suitable for the investigation because of their size. The reflectors, about 25 feet in diameter, allow the capture of a large amount of energy from solar broadcasts. By automatic control, the mirrors will be directed at the sun constantly throughout the day. The first receiver is now in process of installation and will be used, initially, for studies in the 480- to 500-megacycle band.

With the use of higher and higher frequencies in communication and radar equipment, both solar and cosmic noise have come to be recognized as increasingly important. Recent advances in design for both very-high and ultra-high frequency receivers, which practically eliminate internal set noise, indicate that the limiting factors in the use

of the equipment will be those arising from natural phenomena as solar and cosmic noise.

Three general types of external noise that affect radio reception are of scientific interest. The first is atmospheric radio noise, or "static" originating within the earth's atmosphere which, with its characteristic crackle and crash, is familiar to every radio listener. This type of noise is actually the reception of radio energy produced by a lightning discharge. Extreme and prolonged static in the North American continent is generated for the most part in the Caribbean and South American thunder storm regions. Individual flashes of lightning not only accumulate to produce almost steady noise, but also are transmitted over long distances in exactly the same fashion as manmade signals.

Atmospheric radio noise ceases to be a major problem above about 15 megacycles, but it is at this frequency that cosmic noise becomes noticeable. Unlike the radio noise of terrestrial origin, cosmic, radio noise exists as a low steady hiss. In the case of FM equipment, the FM signal itself tends to suppress this noise within a certain range of the transmitting station. However, as distance from the station increases, the ratio between the strengths of the competing signals changes in the favor of cosmic noise until it completely drowns out the FM signal. The main center for the generation of cosmic noise is the constellation Sagittarius in the Milky Way. Because of this, there is a slow change in noise intensity as the position of the earth changes relative to the constellation.

Because of the similarity of the sound produced in the receiver, it has been suggested that cosmic noise may be due to radiation emitted by the thermal agitation of charged particles. The stars of the Milky Way throw off a large amount of material, which expands and tends to fill the intervening space as a very tenuous gas. Under the action of starlight, these atoms of gas are ionized with the production of positively and negatively charged particles, which radiate visible light and may also serve as sources of radio radiation.

Solar noise, which appears at ultra-high frequencies, has a basic component much like cosmic noise—a steady hiss. However, it also has an undulating component superimposed upon the stable noise. These variations are sometimes of great rapidity and manifest themselves in the form of "puffs" and "swishes" lasting a second or less. The swishes may overlap, giving rise to a grinding noise which may cause streaking on a television screen and picture jumpiness. Intense bursts of solar transmission that last as long as several hours cause a radar to become blind when pointed in the direction of the sun.

In the field of cosmic noise, the two chief problems to be solved are the determination of the intensity-versus-frequency function of the radiation and a more accurate survey of intensity versus position at

a variety of frequencies. Both of these problems are being attached at the Bureau. To investigate the first, a series of measurements are being made over the frequency range from 25 to 110 megacycles by means of a battery of specially designed receivers, each tuned to a particular frequency. The second problem requires the highest possible resolving power, which may be obtained either by going to higher frequencies or by using larger collectors. Both lines of attack are to be employed.

Comprehensive data on radio waves of celestial origin are expected to be useful in several applications. For example, a radio sextant might be built to determine position from the direction of arrival of solar noise. This device would permit navigation by the sun even though the sky is overcast and would have some advantage over loran in that it would be completely independent of ground stations.

RADIO PROXIMITY FUZE IN FIRE FIGHTING.

Airborne fire extinguishers equipped with the radio proximity fuze appear to offer a rapid and practical means for combating forest fires, according to extensive tests in which the Bureau participated, along with other Government agencies, during the summer. Characteristics of the radio proximity fuze [1] make it particularly adaptable for fire fighting. Because it bursts the fire-extinguishing bomb at the desired height above the ground, it sprays the extinguishing material, which may be water or a fire-smothering chemical, over the burning area. If the bomb does not burst until it hits the ground, nearly half of the material in the bomb remains in the crater and the remainder is sprayed over a very narrow area.

The radio proximity fuze, developed at the Bureau during the war, is an extremely small and tough radio sending and receiving station. Immediately upon being released, it begins to transmit radio signals. These signals are reflected back to the fuze from the ground, and when they reach a certain intensity or strength, the receiver triggers an electronic switch that detonates the bomb.

Millions of acres of timber are destroyed each year by forest fires in all parts of the country. In the Northwest forestry area, for instance, an average of 1,200 fires are caused by lightning alone during the months of July and August. Many of these occur in remote areas that cannot be readily reached with ordinary fire-fighting equipment. Aerial bombing, successfully carried out, provides a means for checking such fires as soon as discovered and preventing their spread.

The bombs for these tests were constructed from 165-gallon auxiliary fighter fuel tanks stabilized with the 2,000-pound general-purpose bomb fin. A fuze well was installed in the nose, and a burster well extended

[1] See "Radio Proximity Fuze," NBS Technical Bulletin **31**, p. 3 (January 1947).

through the tank. The burster well included a charge to rupture the tank and disperse the extinguishing material after the proximity fuze had functioned.

Fires were purposely started in both brush and dense timber in the mountainous terrain of the Lolo National Forest in northern Montana. A B-29 bomber was used for tests of level bombing and P-47 *Thunderbolts* for dive and glide bombing. Forty-two bombs with proximity fuzes were dropped. Although the containers were not designed for bombing and ballistic data were not available, the accuracy of the bombing, particularly from the B-29, was very good. Improved accuracy, however, should be possible with bombs of known ballistic properties.

Plans for future tests include the use of foam instead of water, which should give a better extinguishing blanket and a better indication of the pattern. Other sizes of bombs will also be used, including a 4,000-pound light-case bomb that holds 260 gallons of foam, and a 500-pound light-case bomb holding 23 gallons; both of these will have proximity fuzes. In addition, tests are to be made with the 100-pound chemical bomb case, with a capacity of 8 gallons of fire extinguishing liquid; these will not be equipped with proximity fuzes.

The tests were conducted cooperatively by the United States Forestry Service and Army Air Forces, with assistance of National Bureau of Standards as representative of Office Chief of Ordnance. National Bureau of Standards prepared and furnished specially prepared VT fuzes and supervised their assembly and use. Flying was done by AAF and ground operations by USFS, centered at the Army Air Base, Great Falls, Montana, and at Forestry Headquarters for the Northwest Area, Missoula, Montana, respectively.

INSTITUTE OF NUMERICAL ANALYSIS ESTABLISHED.

Plans have been completed for the establishment of one of the newest units of the National Bureau of Standards—the Institute of Numerical Analysis—at the University of California at Los Angeles, according to an announcement by Dr. Edward U. Condon, Director of the Bureau.

One of the giant high-speed electronic computing machines, now under development by the Bureau of Standards, will be installed at the Institute when completed. These computers will solve problems in minutes that now take days to work out, and will solve in days problems that are now out of the reach of scientists. Design specifications call for high memory capacity and automatically sequenced mathematical operations from start to finish at speeds attainable only with electronic equipment.

The machines can conceivably revolutionize the field of applied mathematics. Of particular importance both to the physical sciences

and to technical industries will be the fact that the Institute will be able to set up a mathematical counterpart of an actual situation, which permits the situation then to be studied through relatively inexpensive calculating rather than costly experimentation. Great as has been the progress of the past century, the time has come when many problems of great importance, especially in hydrodynamics, aerodynamics, and meteorology, can only be handled by computers working at speeds measured in millionths of a second.

The Institute has two primary functions. The first is research in applied mathematics aimed at developing methods of analysis which will extend the use of the high-speed electronic computers. The second is to act as a service group for Western industries, research institutions, and government agencies. The service function will include not only the use of the machines for problem solving but also assistance in the formulation of problems in applied mathematics of the more complex and novel types. Service operations are to be initiated immediately, using the latest types of commercially available computing equipment.

The decision to locate the Institute at the University of California at Los Angeles was made after a nation-wide survey by the National Bureau of Standards. Centers in the East and Middle West were considered as well as the Far West, but Los Angeles, it was decided, offered the widest range of possibilities for an Institute of Numerical Analysis. Concentration of aircraft industries and the presence of several major scientific institutions were critical in the choice of Los Angeles.

HOME-PLUMBING STUDIES USE PLASTIC PIPE.

Hydraulic engineers at the Bureau are making a study of plumbing systems in which ordinary home plumbing is exactly duplicated except in one important respect—all of the pipes are made of plastic. The transparent pipes are being used so that investigators can see what's actually going on in a typical plumbing installation. This is supplemented with the data gathered from conventional pressure and water-level gages.

The research—directed at some of the more controversial plumbing problems—is being sponsored by the Housing and Home Finance Agency for the Uniform Plumbing Code Committee. Motion pictures are being made of the important tests so that local groups throughout the country can have visual facts to work with when plumbing code revision is under consideration.

Full-scale plumbing systems for two one-story houses and one two-story duplex have been erected. To complete the authenticity of the set-up, building and street sewers of conventional material were installed and means provided for loading the street sewer with a flow of up to 300 gallons per minute.

Three problems so far have occupied the investigators. They are: (1) self-siphonage; (2) stack venting; (3) wet venting. All three are problems connected with the proper venting of fixture traps.

Self-siphonage occurs when the length of the unvented waste pipe from the fixture—for example, the lavatory—is sufficiently long so that the water in the trap is pulled out by suction when the fixture is discharged. In plumbing drainage systems it is necessary to vent, in some manner, each fixture trap. The purpose of the vent is to keep pressures in the fixture drains sufficiently low so that the water seal in the fixture trap is not broken. Stack and wet venting are different methods of accomplishing this result. In stack venting the individual fixture wastes are led directly to the vertical stack, and the stack itself serves, under certain conditions, as a vent for the fixture attached to it. In wet venting, the drain from one fixture serves as a vent for the trap of another fixture.

Each of the above problems is being investigated under many different conditions, involving various lengths, diameters and slopes of fixture drains, various types of traps, and other variables.

That there has been no agreement among the experts in the field is attested to by the variance in plumbing code requirements in municipalities through the nation. It is expected that these investigations will establish facts which will be useful in leading the way to optimum conditions and requirements.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, WEDNESDAY, MARCH 17, 1948.

The Stated Monthly Meeting of The Franklin Institute was held on Wednesday, March 17, 1948, at 8:15 P.M. in the Lecture Hall. Mr. Richard T. Nalle, President of the Institute, presided. There were approximately 375 persons in attendance.

The President announced that the minutes of the Stated Monthly Meeting of January had been printed in full in the February issue of the JOURNAL and if no additions or corrections were offered from the floor the minutes would stand approved as printed. There was no contrary motion.

The Secretary was then called upon for his report. He announced the following members had been elected to the Institute membership in the month of February.

Active	31
Associate	11
Student	17

It was then reported that the total membership in The Franklin Institute as of February 29 was 5412.

The Secretary then announced the Second Engineering Progress Show, which will be sponsored similarly to the previous one held last April, will be held in Franklin Hall from May 11 to May 16, inclusive, from noon till 9 P.M. each day. In addition to the Show itself there will be lectures in the Hall by distinguished engineers on the evenings of May 11, 12, 13, and 14.

The President presented Dr. E. U. Condon, Director of the National Bureau of Standards, Washington, D. C., who delivered a very comprehensive address on the work carried on by the Bureau of Standards.

Dr. Condon spoke of the inception of the Bureau of Standards and the activities of the Bureau in the fields of mathematics, physics and allied science. He said, however, that no work on medicine, food or biochemistry was done at the Bureau of Standards except on equipment that is used in those fields. Dr. Condon said that a great deal of military work was being done but at the present could not be discussed in detail. He presented a general picture of the testing and calibration services of the Bureau.

HENRY B. ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, March 10, 1948.)

HALL OF THE COMMITTEE,
PHILADELPHIA, MARCH 10, 1948.

DR. JULIAN W. HILL in the Chair.

The following reports were presented for final action:

No. 3131: Houdry Process of Catalytic Cracking.

This report recommended the award of a Howard N. Potts Medal to Eugene J. Houdry, of Ardmore, Pennsylvania, "In consideration of his leadership in the development of the im-

portant process of catalytic cracking of petroleum that bears his name, utilizing known basic chemical and physical facts."

No. 3190: Levy Medal.

This report recommended the award of a Louis Edward Levy Medal each to Jan A. Rajchman and William A. Cherry, both of Princeton, New Jersey, "In recognition of their outstanding paper 'The Electron Mechanism of Induction Acceleration', appearing in the April and May 1947 issues of the JOURNAL OF THE FRANKLIN INSTITUTE."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from 9 A.M. until 5 P.M., Wednesdays and Thursdays from 2 A.M. until 10 P.M.

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Principles of Jet Propulsion and Gas Turbines, by M. J. Zucrow. 563 pages, 15 × 24 cm., tables, and drawings. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1948. Price, $6.50.

A Practical Evaluation of Railroad Motive Power, by P. W. Kiefer. 65 pages, 14 × 22 cm., tables, drawings and illustrations. New York, Steam Locomotive Research Institute, Inc., 1948. Price, $2.00.

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Practical Marine Engineering, by Reno C. King, Jr. 470 pages, 15 × 21 cm., drawings and illustrations. New York, Prentice-Hall, Inc., 1948. Price, $6.00.

BOOK REVIEWS.

AMERICAN ANNUAL OF PHOTOGRAPHY, 1948, Vol. 62. 216 pages, illustrations, 18 × 25 cm. Boston, American Photographic Publishing Co., 1947. Price, $2.00.

This standard photographic annual is so well known that there is little need to comment on its interest and value. In scope it follows the practice of past years containing a group of articles, a section of selected photographs, and a directory section.

The lead article by one of the editors, Frank R. Fraprie, illustrates and discusses sixteen of his prints which have met with unusual success in salon showings. J. W. McFarlane contributes a useful article on the making of photographic exploded views describing several methods. Technical problems are considered by H. C. McKay who writes on the art of exposure, by R. J. LeBlanc who discusses sensitometry, and by T. H. Miller who comments on factors to consider in film selection.

Pictorial possibilities of bridges are treated by W. S. Davis with several revealing examples. The section of photographs has many striking pictures. Technical data about these illustrations are also included. The directory section includes a "Who's Who" in pictorial photography, "Who's Who" in color photography, and "Who's Who" in nature photography. There is, in addition, a list of amateur photographic organizations world-wide in scope.

G. E. PETTENGILL.

THE SCIENTIFIC PAPER, HOW TO PREPARE IT, HOW TO WRITE IT, A HANDBOOK FOR STUDENTS AND RESEARCH WORKERS IN ALL BRANCHES OF SCIENCE, by Sam F. Trelease. 152 pages, 13 × 18 cm. Baltimore, Williams & Wilkins Co., 1947. Price, $2.00.

Essentially a revised edition of the author's book "The Preparation of Scientific and Technical Papers," this remains a practical little volume for students and research workers faced with the problem of writing scientific papers. Among the major topics treated are the arrangement of the paper, revision of the manuscript and preparation of final copy, literature citations, abbreviations of periodical publications, and illustrations. This latter is quite detailed considering the correct proportions of the illustrations and different types such as drawings, graphs, photographs and lantern slides. There are many other helpful hints including the use of tenses, acknowledgments, shipping instructions for illustrations, proofreading, and the use of capitals and italics.

A new feature of the work is a section on the use of the library for research purposes prepared by Miss Amy L. Hepburn. Unfortunately there is one quite outdated statement about the planning of a union card catalogue in Philadelphia. Actually the Union Library Catalogue of the Philadelphia Metropolitan Area was incorporated in 1936, now has well over 3,000,000 cards and since 1937 has been successfully fulfilling its primary function of locating books. Mention might well have been made of the fact that the most important union catalogue in the country is that at the Library of Congress and that there are other regional catalogues besides that in Philadelphia. Likewise, in the section on indexing and abstracting tools, *Engineering Abstracts* is not current, having been published only from 1910 to 1913.

These errors do not affect the essential usability of the book, which contains in addition references to other sources for fuller information.

G. E. PETTENGILL.

TIMBER ENGINEERS' HANDBOOK, edited by Howard J. Hansen. 882 pages, illustrations, 19 × 21 cm. New York, John Wiley & Sons, Inc., 1948. Price, $10.00.

During the past decade there has been considerable research on the use of wood as a structural material, bringing with it the need for the correlation of the data developed. The present book attempts to meet that need in providing a ready tool for the designing engineer.

The preliminary chapters are devoted to basic data, including factors affecting strength of wood, grading rules, working stresses, sizes, and properties of sections. One chapter is devoted to terms used in describing standard grades of lumber and to lumber abbreviations. Weights are fully covered, not only weights of lumber but also those of building materials, roofings, nails, screws, and many other varied substances. Load requirements are given for various kinds of construction.

Then follow design information and data on various constructional elements: beams—simple, continuous and trussed; columns—solid and spaced; trusses; fastenings; and floor systems. A long chapter considers buildings and various aspects of both light-frame and heavy timber construction. Glued laminated construction and plywood are likewise treated in some detail.

An appendix actually comprising more than half the nearly nine hundred pages is a table of uniformly distributed loads. This covers spans ranging from 3 to 50 ft. for beams of various sizes and eleven different fiber stresses. Throughout the entire volume an effort has been made to include all woods used in the United States rather than limiting it to those of any one region.

The usefulness of this volume is readily apparent.

G. E. PETTENGILL.

MAGIC SHADOWS, THE STORY OF THE ORIGIN OF MOTION PICTURES, by Martin Quigley, Jr. 191 pages, illustrations, 15 × 23 cm. Washington, D. C., Georgetown University Press, 1948. Price, $3.50.

From the depiction of a boar trotting along in a "motion" still picture on a cave wall 10,000 or more years ago to April 23, 1896 the date of the "most significant motion picture premiere" with Edison's Vitascope, this volume records the gradual realization of the "art of magic shadows." The first identifiable figure in the development of motion pictures is that of Aristotle who made the experiment of "the square hole and round sun" and noticed the existence of after-images. Archimedes used the burning lens, Roger Bacon worked in optics and he or one of his pupils left a description of the room camera. There are other figures mentioned among whom are A. Kircher, who invented the magic lantern; Joseph Plateau and his magic disc; Eadweard Muybridge who made successive still photographs of a horse in motion; and finally Edison.

One chapter brings the story to Philadelphia and concerns the Langenheims who developed a process for making positives on glass slides, and two members of the Franklin Institute, Coleman Sellers and Henry Heyl, who devised machines for showing "posed" motion pictures.

Mr. Quigley has produced a readable, entertaining narrative of the developments leading to the first successful motion picture machine. It is a story of technical achievement and the

culmination of a long desired goal. One chronology, recording in outline form the important dates in the text, forms an appendix and another is devoted to a bibliography of sources consulted.

G. E. PETTENGILL.

THOMAS JEFFERSON AMONG THE ARTS, AN ESSAY IN EARLY AMERICAN ESTHETICS, by Eleanor D. Berman. 305 pages, illustrations, 14 × 21 cm. New York, Philosophical Library, 1947. Price, $3.75.

Among the great figures in American history is that of Thomas Jefferson. He was a man of many interests who achieved his greatest fame as a statesman. Among his Virginia neighbors, his fame as an architect was nearly as great, and he was responsible for the designing of many of the great houses in that state.

In the present volume Dr. Berman has considered Jefferson's relations to all the various arts in which he played a part or in which he was interested. These include painting, sculpture, architecture, gardening, music, oratory, rhetoric and poetry, fiction and letter writing. She traces the derivation of Jefferson's esthetic doctrines and considers each of the arts in relation to one another. Documented, and with illustrations and index, this is an interesting study about our third president.

G. E. PETTENGILL.

ORGANIC SYNTHESES, AN ANNUAL PUBLICATION OF SATISFACTORY METHODS FOR THE PREPARATION OF ORGANIC CHEMICALS, VOL. 27. 121 pages, 15 × 23 cm. New York, John Wiley & Sons, Inc., 1947. Price, $2.25.

To those familiar with earlier volumes of Organic Syntheses the appearance of a new volume with thirty-six additional syntheses will be welcome news. For those who may not know the series, each volume contains some thirty to forty preparations of compounds which are of general interest or which illustrate useful synthetic methods. Compounds are entered under the names commonly used, with the *Chemical Abstracts* indexing name also given if it is different. The formulas indicating the reactions are followed by the names of the submitters and checkers.

The procedure is given with clarity of detail and is accompanied by notes indicating sources of supply, or variations in procedure. Appropriate warning is given of poisonous or otherwise dangerous procedures. The range of yield is reported as are also such data as melting point, boiling range at various pressures, and the refractive index. A section on methods of preparation lists the different methods with citations to the literature. A cumulative index of Volumes 20 to 27 is included.

With each preparation checked to insure accuracy, the series assumes an important place for those who need ready access to tested preparations of organic syntheses.

G. E. PETTENGILL.

THEORY OF SERVOMECHANISMS, edited by Hubert M. James and others. 375 pages, drawings, 16 × 23 cm. New York, McGraw-Hill Book Co., 1947. Price, $5.00.

This twenty-fifth volume of the Radiation Laboratory Series (Massachusetts Institute of Technology) is divided into two sections. The first deals with frequency response techniques of servomechanisms, the second with statistical methods. Each section is provided with an extended mathematical introduction and many illustrations.

HENRY N. MICHAEL.

FUNDAMENTAL ELECTRONICS AND VACUUM TUBES, by Arthur Lemuel Albert, revised edition. 510 pages, drawings and illustrations, 16 × 24 cm. New York, The Macmillan Co., 1947. Price, $6.00.

In his text-book the author has treated electronics as fundamental to both the communication and power fields. Also the theoretical principles are illustrated by applications from both fields. Thus the book is especially suited for college electrical engineering courses.

The first part of each chapter contains the basic information, with the specific information and illustrative applications following.

After discussing basic electronic theory the text takes up specific subdivisions in the following sequence: Emission of Electrons, Thermionic Cathodes, Two-Three, and Multi-electrode Thermionic Vacuum Tubes, Rectifiers, Voltage and Power Amplifiers, Oscillators, Modulators, Demodulators, Photoelectric Devices, and Cathode-ray tubes.

HENRY N. MICHAEL.

TEXTILE BRAND NAMES DICTIONARY, by The Textile Book Publishers, Inc., first edition. 377 pages, 16 × 24 cm. New York, Textile Book Publishers, Inc., 1947. Price, $6.00.

This dictionary is a compilation of more than 4,000 names of fibers, yarns, fabrics and garments, obtained originally from the official *Gazette* of the U. S. Patent office (1934 to 1947). It is divided into three sections. The first section lists alphabetically the brand names with their serial numbers, dates of registration, owners, etc. The second section classifies the most important names under several headings—yarns, rayon piece goods, cotton piece goods, synthetics, silks and others. Part three contains an alphabetical list of the companies owning the brand names, with a cross-reference to the page on which they appear in the first section.

This handy book should prove of definite value to manufacturers, convertors, buyers, patent attorneys, and should be readily applicable whenever questions of ownership, invention and registration arise.

HENRY N. MICHAEL.

WATERBURY'S VEST-POCKET HANDBOOK OF ENGINEERING, fourth edition, revised by H. W. Reddick and others. 386 pages, tables, 7 × 14 cm. New York, John Wiley & Sons, Inc., 1947. Price, $2.50.

This handy volume, originally published in 1908 and now appearing in a fourth edition, has been revised and brought up to date. Several new sections have been added covering the fundamentals of mensuration, the fundamental principles of heat transfer and the basic principles of illuminating engineering. Other subjects included are various phases of mathematics, mechanics, heat engineering, electrical engineering, and radio and electronic formulas. Five-place logarithmic and trigonometric tables are given, too. Lists of the notations used appear at the beginning of most sections and an index completes the volume.

In revised form this volume should continue to render useful service in presenting in concise, convenient form useful formulas and data for the engineer.

G. E. PETTENGILL.

ALEXANDER DALLAS BACHE, SCIENTIST AND EDUCATOR, 1806–1867, by Merle M. Odgers. 223 pages, port. 14 × 20 cms. Philadelphia, University of Pennsylvania Press, 1947. Price $2.75.

"Its most distinguished member" was the way the Franklin Institute referred to Alexander Dallas Bache on the occasion of his death. Not only was he a distinguished member but he had also been an active member, having served as one of the Board of Managers, as Corresponding Secretary, as first Chairman of the Committee on Science and the Arts and as Chairman of the Committee on the Explosions of Steam-Boilers, among other duties. Undoubtedly the Institute was also interested in the fact that Bache was the great grandson of Benjamin Franklin for whom the Institute was named, and that he revealed something of Franklin's versatility and furnished "the professional complement to Franklin's amateur interest in science."

Bache was born in 1806 and died in 1867 and during that period he lived two separate and distinct careers. After graduating from West Point at the head of his class, he taught there for one year and then served two years in the Army. At the age of twenty-two years he was appointed Professor of Natural Philosophy and Chemistry at the University of Pennsylvania, a position he held until he was appointed president of the newly proposed Girard College in 1836. His first duty in this latter post, and as it developed his primary one, was to tour Europe to study the schools there and to make recommendations as to the establishment of the college. This survey resulted in the publication of his famous "Report on Education in Europe." Subsequently Bache became the first head of Central High School in

Philadelphia, general superintendent of the city schools and finally returned to the University of Pennsylvania in 1842, where he closed his educational career a year later.

During this early period he had been active in scientific research, particularly in his work on the report of the Committee on Explosions of Steam-Boilers and in his researches on terrestrial magnetism. He had established a magnetic observatory at Girard College which functioned from 1840 to 1845 and he had also made many other magnetic observations on his trip to Europe and around Pennsylvania.

In December 1843 Bache was appointed Superintendent of the U. S. Coast Survey and it was during his administration that the Coast Survey was established as an important scientific agency. Not only did Bache contribute his scientific knowledge to the Survey, but he also developed a competent staff and displayed real tact and diplomatic skill in his relations both in and outside the Survey. He served his country in yet other ways, among which may be mentioned his duties as Superintendent of Weights and Measures of the United States and as a Regent of the Smithsonian Institution. In this latter position he had much to do with persuading Joseph Henry to head the Institution and was influential in shaping its policy. Bache was also instrumental in founding the National Academy of Sciences and was its first president.

Mr. Odgers has given a revealing and sympathetic treatment of his subject. Considerable attention is devoted to Bache's European trip with numerous quotations from his journal which are illuminating. Several chapters discuss Bache's work as a scientist but not so technically that it would confuse the general reader. The final chapter, "The Chief," dwells particularly on his personal characteristics and points up the humanness and friendliness of the man. A thoroughly enjoyable volume, which this reviewer read with great pleasure, it should appeal especially to these groups: educators, scientists, members of The Franklin Institute, and the many other organizations with which Bache was associated. As a picture of one of the men who did his share toward the development of education, science and life in America it will be rewarding reading for everyone.

G. E. PETTENGILL.

SUNSPOTS IN ACTION, by Harlan True Stetson. 252 pages, illustrations, 14 × 21 cms. New York, Ronald Press Company, 1947. Price $3.50.

Frequently one reads in the newspaper that sunspots have interrupted radio communications, yet many readers may be puzzled as to how this happens. In his latest volume, Dr. Stetson, Director of the Cosmic Terrestrial Research Laboratory at Needham, Mass., explains what takes place. This involves the nature of the radiation from the sun, particularly the ultraviolet rays which produce ceilings in the earth's atmosphere responsible for reflecting the waves used in long-distance radio. Sunspots can completely disrupt these reflecting layers through the increased radiation from the sun.

The author also considers other disturbers of radio communication as magnetic storms, northern lights, solar eclipses and the moon, which investigation has revealed shows a relationship between its phases and the quality of radio reception.

Sunspots are described and the various hypotheses as to their origin are set forth, although this still remains a puzzle for the scientist to solve. The periodicity of sunspot maxima is shown and the attempts at prediction of the next maximum are given, with the observation that there are still not sufficient data so that observers agree on their interpretation.

A relation between sunspot cycles and long period changes in the weather or climate has been revealed by Professor Douglass's notable study of tree rings which register the solar cycles through the centuries. Various other possible relationships between sunspots, the weather and living things are discussed in addition to a chapter outlining the theories relating to sunspots and economic cycles which have been advanced.

A bibliography and a table of relative sunspot numbers from 1749 to 1947 are included. Written in a readable style and avoiding highly technical matter, this volume adequately fulfills its purpose of informing the layman as to the present knowledge of sunspots and their effects.

G. E. PETTENGILL.

LES CATHODES CHAUDES, THÉORIE ET PRATIQUE, by Charles Biguenet. 183 pages, illustrations, 14 × 22 cms. Paris, Editions de la Revue d'Optique Théorique et Instrumentale, 1947. Price 300 francs.

This volume on the hot cathodes has been written with the aim of appealing to the specialist as well as to the general scientific public. The author commences with a review of industrial vacuum technique including a description of various pumps and vacuum measuring instruments. The following chapters deal with some of the phenomena of adsorption whose theory is important in the working of cathodes, and with the theory of electronic emission, particular attention being paid to modern conceptions.

In considering the electronic emission of pure metals, primary emphasis is given to tungsten, for which many valuable tables and graphs are included. Molybdenum and mercury are also noted. From the pure cathodes the author turns to a consideration of the composite cathodes, treating first the monoatomic coated cathode of thoriated tungsten and then the various oxide cathodes which are of commercial importance. One chapter is devoted to the manufacture and treatment of oxide cathodes. A concluding chapter discusses other kinds of hot cathodes, principally various barium types.

This new book fills a gap in the French literature on the hot cahode and will be welcomed as an up to date concise review of the subject.

G. E. PETTENGILL.

CIRCUITS AND MACHINES IN ELECTRICAL ENGINEERING, by John O. Kraehenbuehl and Max A. Faucett. Volumes I and II. Second edition. 367 and 470 pages, drawings and illustrations, 15 × 24 cms. New York, John Wiley & Sons, Inc.; London, Chapman and Hall, Limited, 1947. Price $4.25 each.

Since the text of the first edition has been used for electrical engineering students as well as for other engineering students, the authors have changed the material of the second edition to meet both purposes. The 1947 edition is divided into two volumes—one on circuits, one on machines.

The material in the first volume emphasizes the circuit as the basic element in the machine and in the study of machine operation, rather than as a part of the communication circuit. The emphasis is on power.

Some of the major changes of the second edition occur in the chapter on electronics, which has been considerably expanded. The material on ignitrons is new.

The first chapter contains some material on the use of the mks system, all the general text material follows the cgs system.

The second volume deals with electrical machinery only. The machines are treated as direct and alternating-current ones, rather than as generators and motors as in the first edition.

The transformer chapter has been expanded to include a discussion on harmonics.

New problems have been added throughout the text and the attempt has been made to give problems which lead to analysis rather than to substitution into expressions which appear in the developments.

HENRY N. MICHAEL.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Some Factors in the Nessler Method of Nitrogen Determination.—JAMES L. LEITCH. The following factors involved in the use of the Nessler reagent for the determination of nitrogen are discussed in a paper by Miller and Miller (**1**): (1) effect of time and completeness of digestion, (2) effect of addition of hydrogen peroxide and the optimum use thereof, (3) rate of addition of reagent to digested sample, (4) rate of mixing of reagent with sample, (5) stability of color, (6) temperature of final solutions, and (7) effects of interfering substances. The purpose of this paper is to present additional data (*a*) dealing with the effect of the amount of sulfuric acid used for the digestion on the final color intensity, and (*b*) extending the range of the method by the use of various light filters.

Effect of Sulfuric Acid Concentration.—Miller and Miller recommend the use of 0.4 ml. of 1:1 sulfuric acid. When large samples are digested with increased volumes of acid, they dilute the final digest with distilled water and take an aliquot for color development so that it contains the equivalent of 0.4 ml. of 1:1 sulfuric acid. Koch and McMeekin (**2**) vary the amount of Nessler reagent added in relation to the amount of acid used in the digestion so that the final solutions have approximately an alkalinity equivalent to 0.56 per cent sodium hydroxide.

In attempts to use the Miller and Miller method in this laboratory, it was found that slightly low colorimeter readings were obtained at the higher nitrogen levels. These low values were associated with the appearance of a red precipitate of mercuric oxide suggesting that the final alkalinity was too low.

To study further the effects of the sulfuric acid concentration on the final color intensity, standard ammonium sulfate solutions were analyzed with from 0.2 to 0.7 ml. of 1:1 sulfuric acid for the digestion. The method used in these analyses was essentially the short method of Miller and Miller with the following modifications:

1. The volume of sulfuric acid was varied from 0.2 to 0.7 ml.

2. Before the initial period of digestion, two drops of 30 per cent hydrogen peroxide (Superoxol, Merck) were added to eliminate bumping. Miller and Miller have shown that such a procedure may give low results with certain substances. However, for routine analyses, this slight disadvantage is considered to be greatly outweighed by the elimination of the more serious problem of bumping.

3. Repeated inversion for a period of 40 sec. after the addition of the reagent gave satisfactory results.

4. Filter No. 50 was used instead of filter No. 54.

Typical results are summarized in Table I. As a further check on these results, digested samples, after dilution and addition of Nessler reagent,

TABLE I.—*Effect of Volume of 1:1 Sulfuric Acid Used for Digestion on the Intensity of Color Development with 5.0 ml. of Nessler Reagent.*

Volume of 1:1 H_2SO_4 used in digestion, *ml.*	Colorimeter readings with filter No. 50 Micrograms of nitrogen in samples					Remarks
	0	50	100	150	200	
0.20	8	69,68	137,137	206,206	274,274	
	7	68,69	138,137	209,205	273,275	
0.30	6	69,67	137,138	205,205	273,274	
	7	67,68	136,138	206,206	274,275	
0.40	5	68,69	137,137	204,206	268,266	
	4	67,68	137,137	205,201	270,268	
0.45	4	68,66	135,130	202,200	264,264	Slight red precipitate in some samples
	5	65,66	135,134	199,199	262,261	
	6		135,133		260,261	
0.50	0	36,37	108,110	119,181	206,204	Variable amounts of red precipitate in all samples
	5	36,36	116,30	131,162	199,232	
	0		117,95		227,204	
0.55–0.70	Heavy red precipitate in all samples with little or no color in solution.					

were titrated with normal hydrochloric acid using phenolphthalein as indicator to determine the concentration of alkali in the final sample. Representative results of these titrations are given in Table II.

The data in Table I indicate that a straight-line relationship exists between the concentration of nitrogen and the colorimeter reading, provided not more than 0.3 ml. of 1:1 sulfuric acid is used in the digestion. When 0.4 ml. of acid is used, low and somewhat variable results were obtained as the nitrogen content was increased above 150 micrograms. As the concentration of acid is further increased, the color intensity gradually decreases and becomes more variable until at 0.55 ml. and above, a heavy red precipitate of mercuric oxide is formed with little or no color in solution. The data on residual alkalinity as given in Table II indicate that the straight-line relationship is obtained in the presence

TABLE II.—*Residual Alkalinity of Digested Samples after Dilution and Addition of 5.0 ml. of Nessler Reagent.*

Volume of 1:1 H_2SO_4 used, *ml.*	Residual alkalinity	
	As Normality	As per cent NaOH
0.20	0.249	1.00
0.30	0.157	0.71
0.40	0.122	0.49
0.45	0.080	0.32
0.50	0.037	0.15
0.60	Acid to phenolphthalein	

of 0.71 per cent sodium hydroxide but not below 0.49 per cent. These data agree closely with those of Koch and McMeekin who reported satisfactory results with an alkalinity of 0.56 per cent sodium hydroxide. On the basis of these data it would seem advisable to carry out the digestion with not more than 0.3 ml. of 1:1 sulfuric acid. It is realized that greater volumes of acid could be used, providing the volume of the Nessler reagent was also increased so that the final residual alkalinity

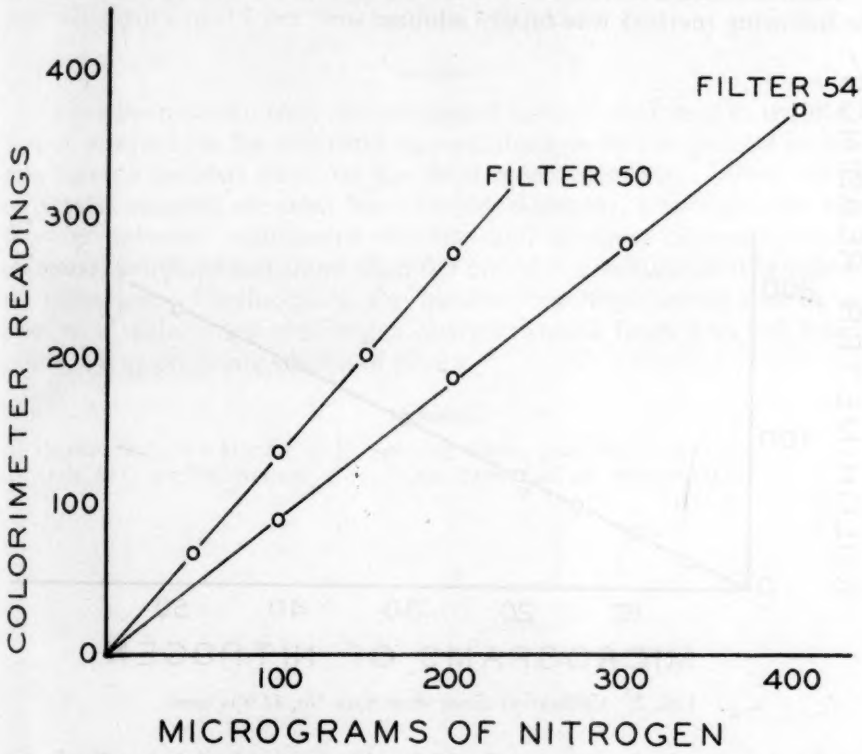

FIG. 1. Calibration curves when filters Nos. 50 and 54 were used.

fell within the optimum range. However, such a change in the procedure would unnecessarily complicate the method.

Relation between Nitrogen Range and Color Filter.—In the method of Miller and Miller, filter No. 54 was used for the determination of nitrogen in the range between 100 and 300 micrograms. In the data reported herein obtained by using only 0.3 ml. of acid for digestion, satisfactory results were obtained with filter No. 54 for samples containing 100 to 400 micrograms, with filter No. 50 for 50 to 200 micrograms and with filter No. 42 for 5 to 50 micrograms of nitrogen, respectively. Representative calibration curves are given in Figs. 1 and 2 for all three filters. One difference was found between the use of filter No. 42 and that of

filters Nos. 54 and 50. With the latter two, a blank reading of from 4 to 8 was always obtained, but the readings of samples containing various amounts of nitrogen did not have to be corrected for this blank value. On the other hand, when filter No. 42 was used for samples containing 5 to 50 micrograms of nitrogen, the data as given in Fig. 2 were obtained only after subtracting the blank value. No explanation can be made from the available data for this peculiarity.

Recommended Procedure.—On the basis of the work reported herein, the following method was finally adopted:

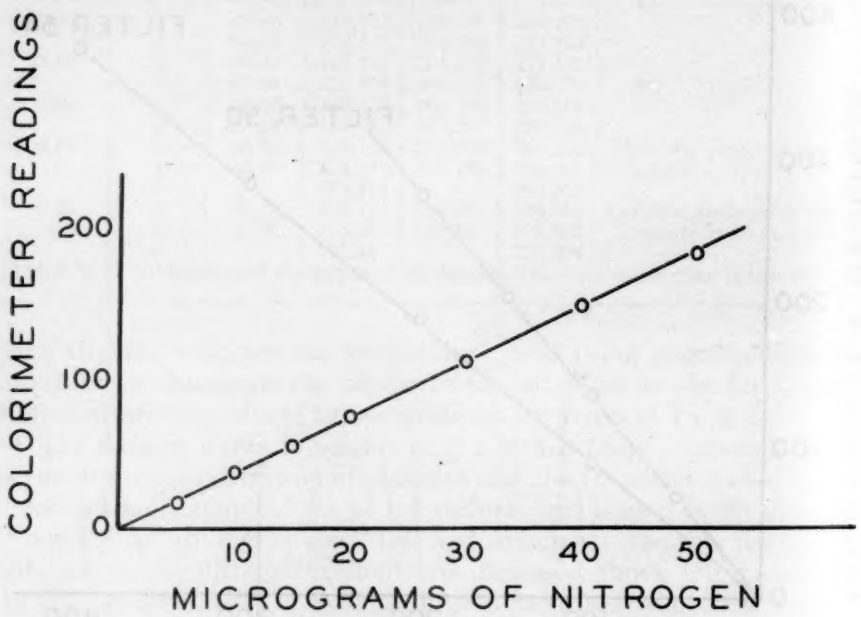

FIG. 2. Calibration curve when filter No. 42 was used.

To the sample (not over 0.5 ml.) is added 0.3 ml. of 1:1 sulfuric acid followed by two drops of 30 per cent hydrogen peroxide (Superoxol, Merck). All digestions are carried out in 18 × 150 mm. Pyrex test tubes. After 5-min. digestion, and cooling for 1 min., Superoxol is added dropwise (usually 2 to 4 drops) to complete decolorization of the sample followed by 2-min. digestion. Cooling, addition of 2 drops of Superoxol and digestion are then repeated twice with 5-min. digestion after the last addition of Superoxol. Additional treatments with Superoxol and additional periods of digestion are used for refractory substances. After completion of the digestion, the samples are allowed to cool for approximately 30 min. before the addition of 20 ml. of distilled water. Then to each sample is added 5.0 ml. of Nessler reagent prepared according to the procedure of Koch and McMeekin. Mixing

of the reagent with the sample is satisfactorily carried out by repeated inversion for a period of 40 sec. after the addition of the reagent. Thirty minutes later, all samples are read with a Klett-Summerson photoelectric colorimeter using the appropriate filter. Analyses were always carried out in duplicate concurrently with suitable standards prepared from ammonium sulfate.

Other volumes of sulfuric acid may be used for the digestion, provided that a volume of Nessler reagent is used sufficient to give a minimum final alkalinity of 0.7 per cent sodium hydroxide.

Summary.

It has been shown that the amount of sulfuric acid used in the digestion of samples for the determination of nitrogen by the Nessler method may have a decided effect on the final color intensity. When 5.0 ml. of Nessler reagent are used for color development, a straight-line relationship between colorimeter readings and nitrogen concentrations is obtained, provided not more than 0.3 ml. of 1:1 sulfuric acid is used for the digestion. Furthermore, the method described herein can be applied to a wide range of nitrogen concentrations, from 5 to 400 micrograms, by appropriate choice of filters.

References.

(1) MILLER, G. L. AND MILLER, E. E., *Ind. Eng. Chem., Anal. Ed., In press.*
(2) KOCH, F. C. AND MCMEEKIN, T. L., *J. Am. Chem. Soc.*, **46**: 2066 (1924).

CURRENT TOPICS.

Iron Ore Supply.—Plans by Lake Superior district iron mining companies for large-scale refining of low-grade iron ore to guarantee American industry a continued supply of high-grade iron are attracting the interest of the engineers of the General Electric Company.

Iron ore companies are turning to the refining or "beneficiation" process, as it is popularly known in the industry, on an industry-wide basis because the supply of high-grade ores will be exhausted in from 20 to 30 years at the present rate of consumption, engineers said.

With beneficiation, the low-grade ores, now plentiful but unmarketable because of their low iron content, will be refined near the mines to increase the grade prior to shipment. Only by this method can the Lake Superior district, which includes the rich Minnesota Mesabi range, continue to supply about 85 per cent. of the nation's annual 60 to 70 million-ton-supply of iron ore, engineers explained.

Electric equipment will be needed by the mining companies in crushing and screening, concentration, and sintering plants, where most of the equipment will be electrically powered, engineers said. This equipment will include generators, motors, transformers, unit substations, switchgear, controls, and other electric apparatus.

General Electric is now supplying some of this equipment for pilot plants in the early stages of the beneficiation program. The company has assigned a special staff of engineers to study approved and new electric systems for the process, and experience is being gained from those industries which have used beneficiation methods for many years.

The new development will also have an important bearing on the power companies in the mining district. Engineers said the new process would require from 60 to 80 kilowatt hours per ton as compared to 1½ to 4 kw.-hr. per ton average for the present methods, which, in most cases, consist only of crushing and washing some ores before shipment.

Two major wars and the great demand for steel products already in the 20th century have resulted in a drain on the high-grade deposits, which were naturally beneficiated by the forces of Mother Nature. Aware they are facing a time limit on high-grade ore production, the mining companies are taking over nature's job on the low-grade ores, and directing their research and economic efforts to beneficiation, it was explained.

The low-grade ores contain about 30 per cent. iron. Known in the iron ore industry as "taconite," it must be refined for smelting, engineers pointed out. Of all Lake Superior ore produced today, only 20 per cent is now beneficiated and shipped to supplement the balance of high-grade ores.

When suitable processes have been worked out, this percentage will become higher, and engineers predict that nearly 100 per cent. of all the ore produced three decades from now will be the low-grade variety, and will require beneficiation.

R. H. O.

Electric Furnace Brazing Facilitates Manufacture of Insecticide Bombs.—Electric furnace brazing greatly facilitates the fabrication of insecticide bombs at the Aer-a-sol Division of the Bridgeport Brass Company, Bridgeport, Conn. Adoption of this method of brazing has inproved the quality of these bombs, simplified their construction, and lowered manufacturing costs. The containers, which are made of SAE-1010 steel .043–.049 inch thick and contain a liquid insecticide under about 90 pounds pressure, are fabricated at an average of approximately 10,000 per eight-hour shift. Two General Electric continuous furnaces are used.

Originally, these containers were fabricated by a bonding method which involved locally heating each joint and using brazing metal and flux. With this method, considerable difficulty was encountered after brazing in removing deposits of charred flux from the interior of the bombs. This was necessary since loose particles tended to clog the .008-inch diameter orifice of the specially designed dispensing valve of the bombs. In addition, there was the ever-present danger of corrosion from moisture trapped in the bomb. Furthermore, a large percentage of the containers leaked.

With electric furnace brazing, inexpensive copper is employed as the brazing metal, and no flux is required. Consequently, the bomb assemblies come from the furnaces clean and bright, no oxides or foreign matter are present, the corrosion and moisture hazard is eliminated, and the bonds are uniformly tight and strong, testing almost 100 per cent. free from leaks. In addition, all four of the assembly joints are bonded simultaneously in a single trip through either of the two continuous furnaces.

With this brazing process, the assemblies are put together with the brazmetal preplaced near the joints to be brazed. As the containers pass through the heating chamber of the furnace, a reducing atmosphere frees the metal from any oxides present, prevents the steel from oxidizing, and thus prepares the parts to be wetted by the molten copper. When the brazing metal melts, it is drawn into the joints of the assemblies by capillary attraction and forms alloys with the steel. Transferred to the adjoining controlled atomosphere cooling chamber, the solidifying alloys develop great strength, and the bombs gradually cool to a temperature at which it is safe for them to come in contact with the outside air without danger of discoloration because of oxidation.

Each of the roller hearth copper brazing furnaces used in this application consists essentially of a heating chamber nine feet in length and an adjoining water-jacketed cooling chamber 30 feet long. The heating chamber is equipped with electric heating units rated 180 kw., divided into two 90-kw. zones, each with separate power and temperature control. The heating units are made of heavy rolled ribbon, formed in sinuous loops, mounted in the roof of the chamber and on the side walls above and below the roller conveyor running through the chamber. The cooling chamber is made of two concentric rectangular steel shells to provide a water jacket, and is divided lengthwise into three sections, each with a separate water circuit. The first section of the cooling chamber has automatic cooling water temperature control, to prevent condensation during idling periods.

Hollow cast alloy rolls are used throughout the charging vestibule, heating chamber, and the first section of the cooling chamber. Solid steel rolls are employed in the remaining sections. Water-jacketed, self-aligning roller

bearings are mounted on the sides of the casing except for the last two cooling chamber sections, which do not require cooling. The rolls are motor driven through a chain and sprocket mechanism.

Each furnace is capable of brazing 700 containers per hour, which is a production of 700 pounds net, or 1,352 pounds gross per hour. For this rate of production, the power consumption is about 157 kw.-hr. per hour. Consumption of combusted gas for the furnace atmosphere is about 1,500 cubic feet per hour, which is made by burning about 675 cubic feet per hour coke oven gas.

Throughout, the bombs are fabricated almost entirely on an assembly line basis. Belts or roller conveyors carry them from one operation to another until they arrive at the furnaces, where they are manually placed in the brazing trays. The trays are then automatically charged into the furnaces and travel slowly through them on motorized conveyors. After being discharged from the furnaces and inspected, the dispensing valves are added and the bombs are air-tested, marked, and charged with liquid insecticide and then with Freon under pressure. Attached to an overhead chain conveyor, they are cleaned, lacquered, and again inspected. A belt conveyor carries them to the final station, where they are labelled, visually inspected, and finally packed for shipment.

R. H. O.

50 Per Cent of Perishables May Be Frozen by 1960. (*Refrigerating Engineer*, Vol. 53, No. 5.)—Government economists recently declared that within 10 years, 50 per cent of all perishable foods will be preserved by freezing. Today, though the amount of food frozen has increased 300 per cent since prewar, only 2 per cent of the country's perishable foods is frozen.

Frozen food interests look to trucks for a big share of the unprecedented task of moving literally millions of tons of food at temperatures of zero or colder, the Refrigeration Equipment Manufacturers Association has declared. Frozen food economists estimate that more than 10,000 new refrigerated trucks and trailers are needed at once for coast-to-coast shipments and door-to-door deliveries and that lighter, smaller, and more economical refrigeration equipment for truck installation must be produced in quantity.

In production today are units for trucks of all types which supply the necessary zero temperatures. Temperatures as low as −10 F. with outside temperatures of 110 F. are obtained within properly insulated reefers by means of so-called packaged units. For the large semi-trailers, models supplying two tons of refrigeration are most frequently used, while for the somewhat smaller direct mounted bodies there are models at one ton capacity.

Push-button operation and automatic temperature control require little attention from the truck driver. Cargoes of fresh produce can be transported on one stretch of the trip and by changing the dial setting for lower temperatures, a load of frozen food can be carried on a return trip. Dial settings on this equipment make it possible to provide a wide range of temperatures, depending upon the kind of perishable produce to be transported.

R. H. O.

New Process Control Instruments.—New electric measuring instruments, capable of providing a continuous analysis of flowing streams of fluids and gases, together with automatic control of those processes, give promise of advances for the chemical industry.

This was recently revealed in a paper presented before the annual meeting of the Institute of Chemical Engineers. The speaker was Everett S. Lee, chief engineer of General Electric's General Engineering and Consulting Laboratory at Schenectady, N. Y.

Speaking on "New Process Control Instruments for the Chemical Industry," Mr. Lee described several instruments recently developed "which measure basic quantities to give opportunity for continuous analysis of a flowing process stream." He asserted that chemical industry spokesmen long have pointed to such devices as the industry's greatest need in the field of instrumentation.

"A particularly interesting example of the new process control instruments for the chemical industry is the X-ray photometer, which provides economical and rapid means of making chemical comparisons," Mr. Lee said. "With this instrument it has been found possible to determine satisfactorily the tetraethyl lead content of gasoline, the concentration of an acid in water, the per cent chlorination of a plastic, or the per cent ash in coal. These determinations are made by measuring and comparing X-ray absorption of a sample and a reference."

An outstanding advantage of this method of comparison lies in the fact that X-ray absorption always is the same for a given material, whether it is hot or cold, gaseous, liquid, or solid, or whether the element being measured is alone or in chemical combination. Too, analysis is made without loss or alteration of the sample tested.

R. H. O.

Oregon Installs Radiant-Heated Road. (*Engineering News Record*, Vol. 139, No. 18.)—To end winter skidding danger on an 8 per cent highway grade separation at Klamath Falls, the Oregon Highway Department is now building a section of radiant-heated pavement. This steep grade will be winter-proofed by an adaptation of radiant panel heating making use of nearby natural hot springs as a heat source.

A similar idea was used last winter in Belmont, Mass.

A 10-in. well 250 ft. deep near the highway provides natural hot water, with temperatures up to 220 F. A 2-in. main runs from the well to the pavement and parallels it for about 400 ft. In the pavement slab is placed $\frac{3}{4}$-in. pipe, 18-in. o.d., in 60-ft. panels. Each panel will be connected with the 2-in. hot-water main by valves which will assure an even flow of water through each panel.

The 2-in. main and the series of 60-ft. panels of $\frac{3}{4}$-in. pipe will comprise a closed circuit. Hot water from the wells will not be allowed to enter this circuit. Instead, the circuit will be filled with ordinary water in which antifreeze solution will be introduced. This water will be warmed by means of a heat transfer unit comprised of 2-in. pipe extending close to the bottom of the well in order to obtain maximum immersion. Inserted in the closed circuit will be a pump, thermostatically controlled. When air temperature drops to

the freezing point, the pump will automatically start, circulating the water through the closed circuit. At the same time, another pump will begin exhausting hot water from the well at a rate sufficient to maintain the maximum temperature in the well. Unless hot water is so exhausted, constant circulation of the cold water through the heat transfer unit will have a tendency to cool off the well.

The pumps will continue to operate until air temperatures rise above the freezing point.

R. H. O.

New Airplane Catapult. (*Electrical Engineering*, Vol. 66, No. 10.)—The "electropult," an unusual type of induction motor manufactured by the Westinghouse Electric Corporation, Pittsburgh, Pa., is designed for launching airplanes that require long take-off runs from small landing fields without the high inertia impact imparted by other catapults. The secondary winding of the motor is the track of the catapult, and its primary winding is the car to which the airplane is harnessed.

Two electropults are now in use by the Navy, one at Mustin Field, Philadelphia, Pa., and a larger one at the Naval Air Test Center, Patuxent River, Md. The track of the larger unit is 1,382 feet long, and is made up of 76 sections with 12-inch active core width, that are set flush with the surface of the runway. Resistance of the first 1,000 feet of track is decreased progressively in four steps. This graduation of resistance enables the tractive force to be held substantially constant as the speed is increased. The last 382 feet are used for stopping the car by dynamic braking and application of direct current.

The car projects only $5\frac{1}{2}$ inches above the surface of the runway. On the under side of the car is the 3-phase primary winding in a flat core at a working air gap of $\frac{3}{16}$ inch. The car wheels run on rails recessed in slots which straddle the stationary secondary winding, and a set of rails above the wheels prevents the car from being lifted. A space under the track houses the bus bars and collector rails that carry approximately 7,000 amperes during acceleration and 10,000 amperes during braking. The current collecting problem is extremely difficult because the car attains a speed of 225 miles per hour. The 12 collector shoes per phase are held against the collector rails by spring pressure. Provision is made for the pilot of the airplane to release the harness at the proper time.

One of the features of the launcher is a short-time power demand of approximately 12,000 kw. The power supply consists of a 2,200-horsepower aircraft engine coupled to a 750-kw. d-c generator which supplies a d-c motor connected to a 24-ton flywheel and 3-phase alternator that supplies the catapult car. During the short time required to launch an airplane, the flywheel loses speed to furnish approximately 95 per cent. of power needed. Slowing down of the flywheel and alternator reduces the frequency from 216 to about 192 cycles per second.

The electropult has launched jet-propelled airplane at 116 miles per hour in 4.1 seconds after a run of only 340 feet. Unassisted, the same airplane requires a take-off run of approximately 2,000 feet.

R. H. O.